GRAPHIC Nobel

Nobel prizes in physics explained with cartoons

1901 – 1910

Manu Cornet

For my brilliant physics and chemistry teachers (in order of appearance in my personal movie): Jérôme Bonaldi, Michel Lagouge, Stéphane Mansuy, Jean-Philippe Bouchaud, Bernard Castaing and Walter Lewin.

Many thanks to Annie Chen, Nadine Ho, Sara Segel, Denise Wang and Monica Wright for reading early versions of this book and providing valuable feedback.

I loathe forewords and prefaces, and I'm sure you do too. So here we go.

This book was made exclusively with open source software.

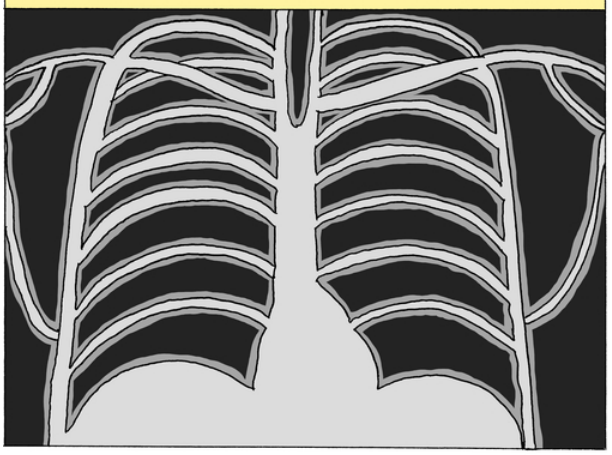
ISBN 978-0-98-852386-9

1901

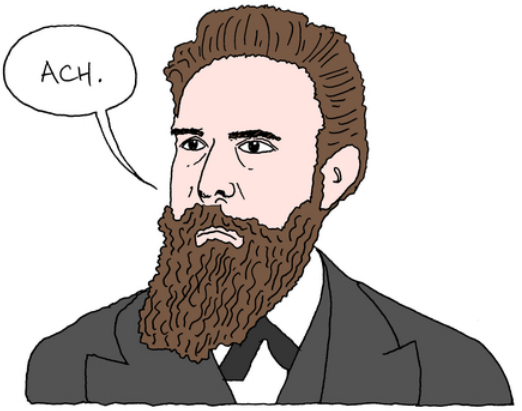
WILHELM RÖNTGEN

In recognition of the extraordinary services he has rendered by the discovery of the remarkable rays subsequently named after him.

"X-RAY" PROBABLY MAKES YOU THINK OF THIS:



WELL, WE ALL HAVE THIS GRUMPY LOOKING 19/20th CENTURY GERMAN GUY TO THANK FOR THOSE RAYS:



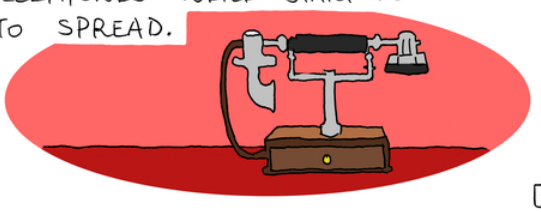
NOW TRY TO PICTURE YOURSELF BACK IN 1895...

THE FIRST CARS WERE BEING COMMERCIALIZED.

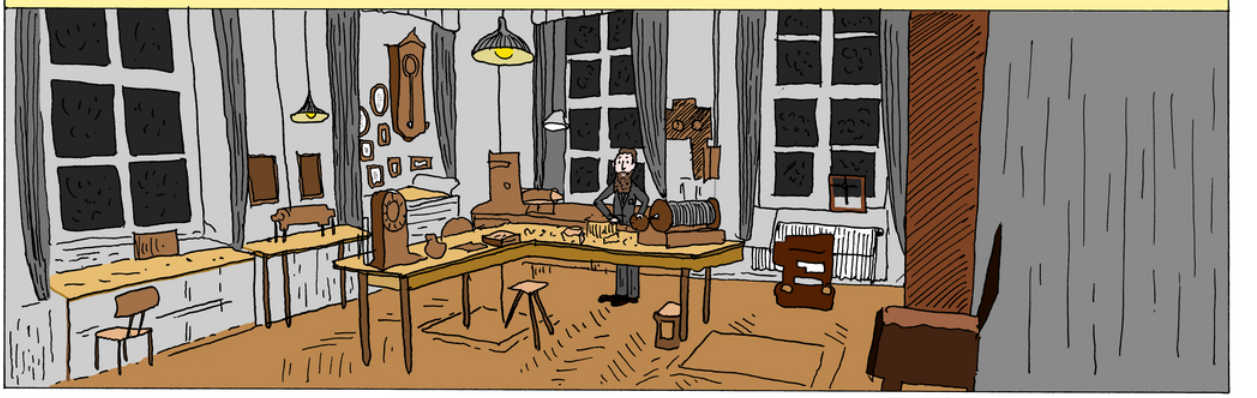
THE FIRST MOVIES WERE BEING SCREENED IN PUBLIC.

OSCAR WILDE WAS CONVICTED BECAUSE OF HIS HOMOSEXUALITY.

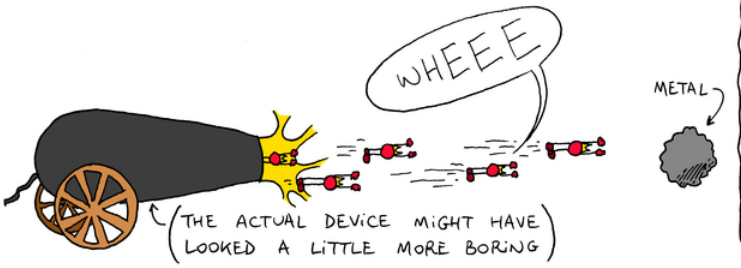
TELEPHONES WERE STARTING TO SPREAD.



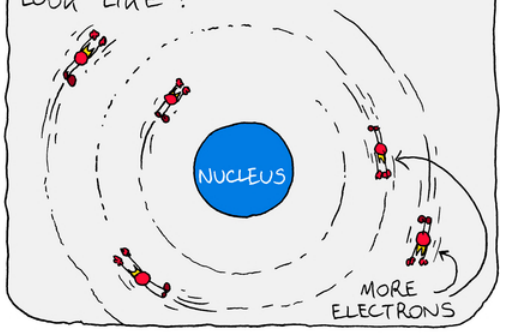
AND HERE IS OUR MR RÖNTGEN SLAVING AWAY IN HIS LABORATORY ON A FRIDAY NIGHT (NOV 8TH 1895).



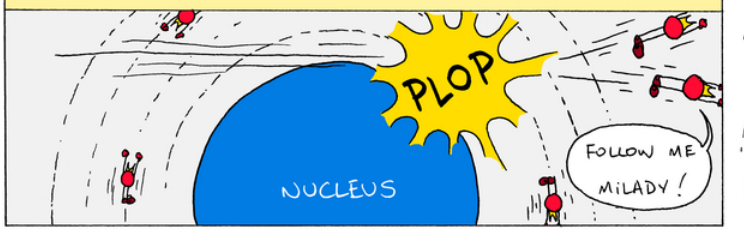
HE WASN'T LOOKING FOR X-RAYS AT ALL, BUT HE WAS PLAYING WITH A DEVICE THAT COULD SHOOT ELECTRONS LIKE A CANNON. AND HE HAPPENED TO POINT IT AT A PIECE OF METAL.



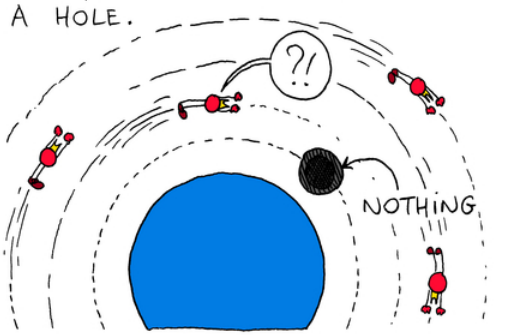
OF COURSE THE METAL IS MADE OF ATOMS. REMEMBER WHAT THOSE LOOK LIKE?

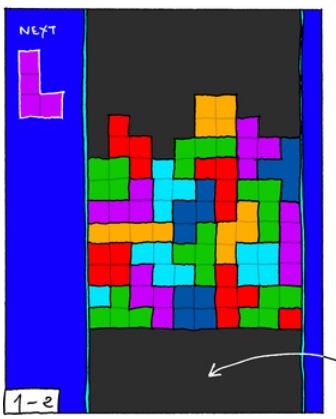


SO WE HAVE A LARGE BUNCH OF SEDENTARY ELECTRONS BEING BOMBARDED BY A STREAM OF HIGH-SPEED ELECTRONS. MANY COLLISIONS HAPPEN AND ELECTRONS GET KNOCKED OFF.

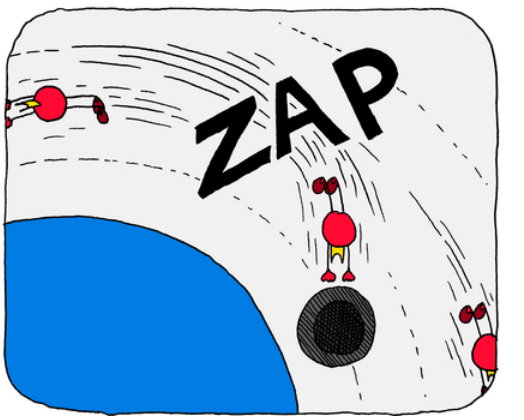


WELL, AND NOW WE HAVE... A HOLE.

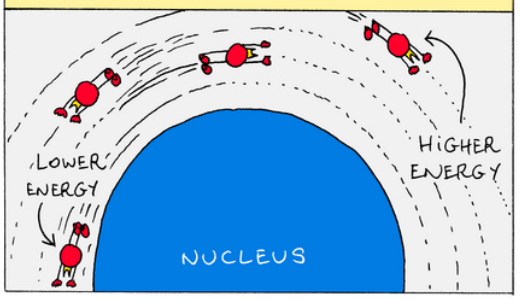




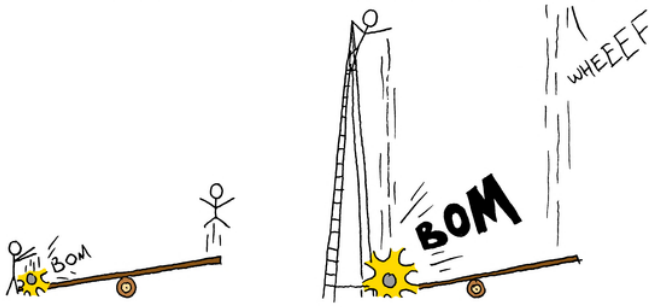
IF YOU'VE EVER PLAYED TETRIS, YOU KNOW THAT SUCH A HOLE WILL NOT LAST VERY LONG...



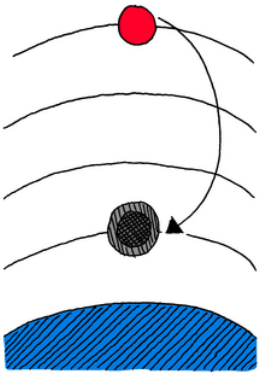
IN AN ATOM, THE FURTHER AWAY ELECTRONS ARE FROM THE NUCLEUS, THE HIGHER THEIR ENERGY.



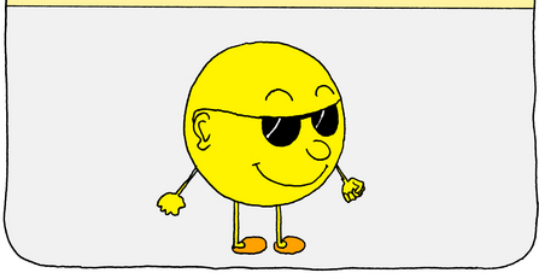
IT'S A BIT LIKE LIFTING A ROCK FROM THE GROUND. IF YOU LIFT IT HIGHER, IT HAS MORE POTENTIAL ENERGY IT CAN RELEASE WHEN YOU DROP IT AGAIN.



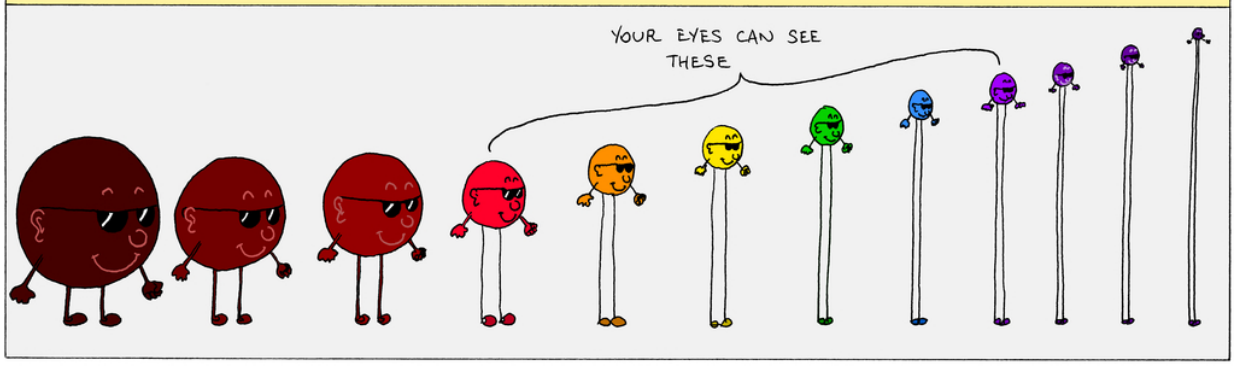
SO IF AN ELECTRON FROM A LOWER ENERGY RUNG IS KICKED OUT AND ITS SPOT IS TAKEN BY A HIGHER ELECTRON, THAT ELECTRON LOSES ENERGY.



BUT WHAT DOES THAT ENERGY BECOME? PLEASE MEET MR PHOTON.



A PHOTON IS JUST A TINY CHUNK OF LIGHT. AND THEY COME IN A WHOLE RANGE OF FLAVORS.

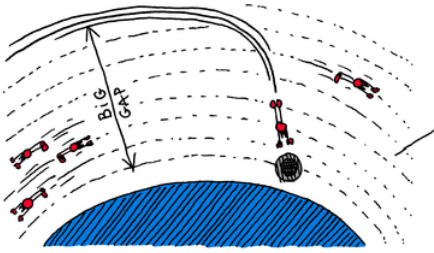


EACH FLAVOR IS CHARACTERIZED (AMONG OTHER THINGS) BY HOW MUCH ENERGY IT HAS. IN OUR METAPHOR HERE, LONGER LEGS REPRESENT MORE ENERGY.

LOW ENERGY

HIGH ENERGY

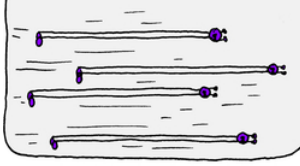
REMEMBER OUR ELECTRON WHO JUMPED INTO THE NEWLY VACANT SPOT BELOW HIM? WHEN THAT ATOM HAS A LOT OF ELECTRONS, THE GAP CAN BE QUITE LARGE...



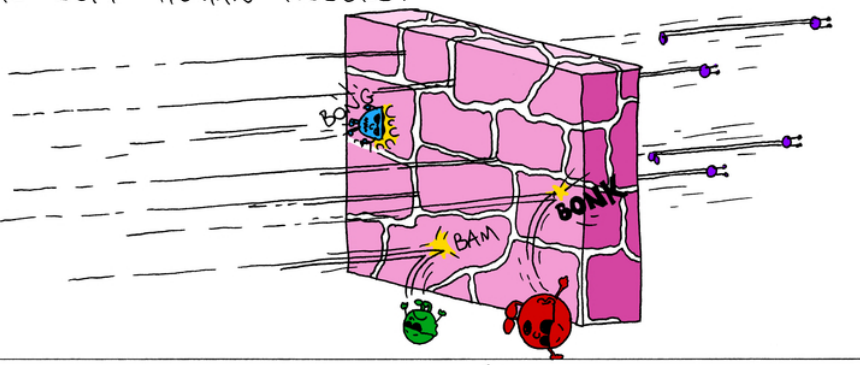
BIG CHUNK OF LOST ENERGY

... A PHOTON GETS EMITTED, AND IT NEEDS TO BE THE KIND THAT CARRIES A LOT OF ENERGY.

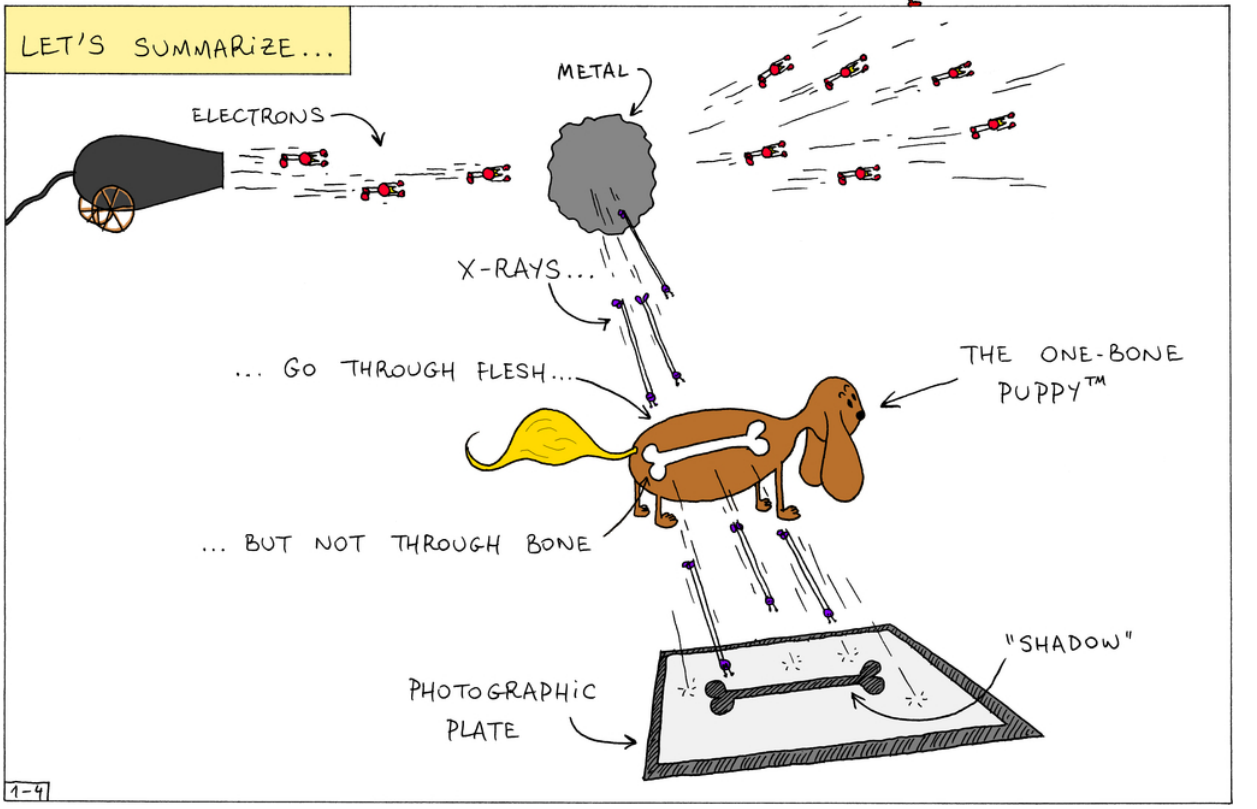
AS YOU MAY HAVE GUESSED, X-RAYS ARE MERELY A SPECIAL KIND OF LIGHT, MADE OF THESE HIGH ENERGY PHOTONS.



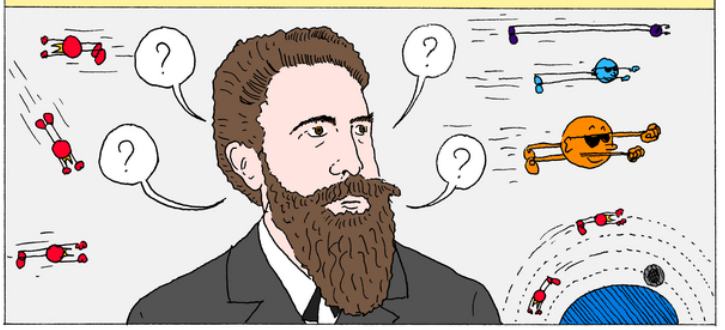
THEY'RE SPECIAL BECAUSE THEY CAN GO THROUGH THINGS OTHER (LOWER ENERGY) PHOTONS CAN'T, SUCH AS SOFT HUMAN TISSUES.



LET'S SUMMARIZE...

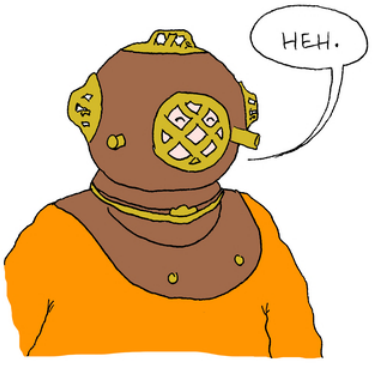


IT IS WORTH NOTING THAT OUR DEAR MR RÖNTGEN (AND OTHER PHYSICISTS AT THAT TIME) DIDN'T KNOW MUCH ABOUT THE ATOMIC STRUCTURE, ELECTRONS TRANSITIONING BETWEEN ENERGY LEVELS, ETC. HE MERELY STUMBLED UPON THIS UNKNOWN TYPE OF RAYS WITH INTERESTING PROPERTIES.

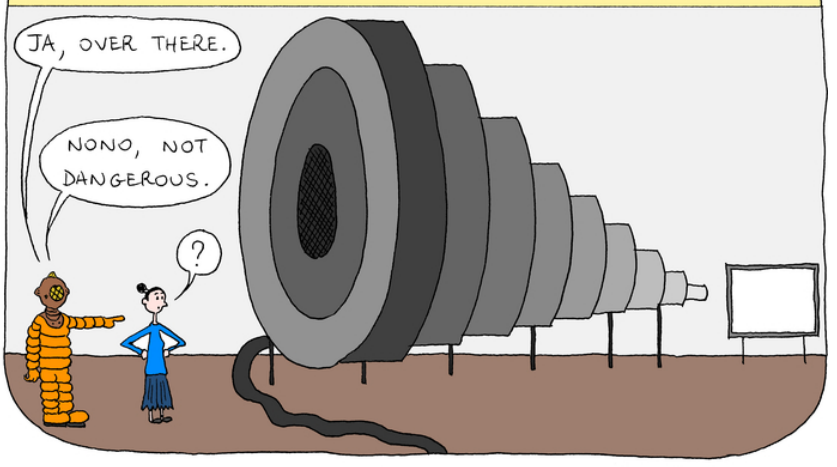


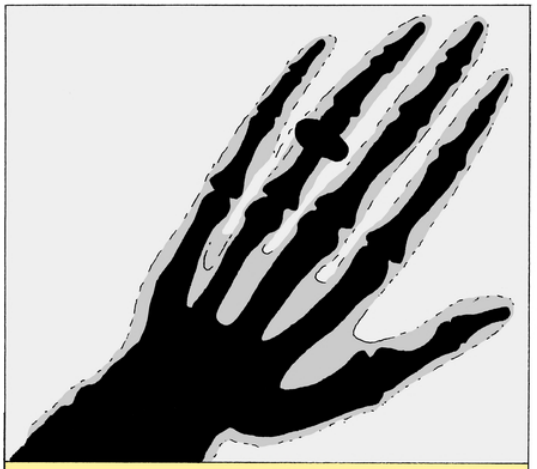
BUT HE VERY QUICKLY SAW THE POTENTIAL MEDICAL APPLICATIONS OF HIS DISCOVERY.

AND HE WAS WISE ENOUGH TO PROTECT HIMSELF FROM THIS LITTLE-KNOWN PHENOMENON.



THE VERY FIRST HUMAN X-RAY WAS OF RÖNTGEN'S WIFE'S HAND.

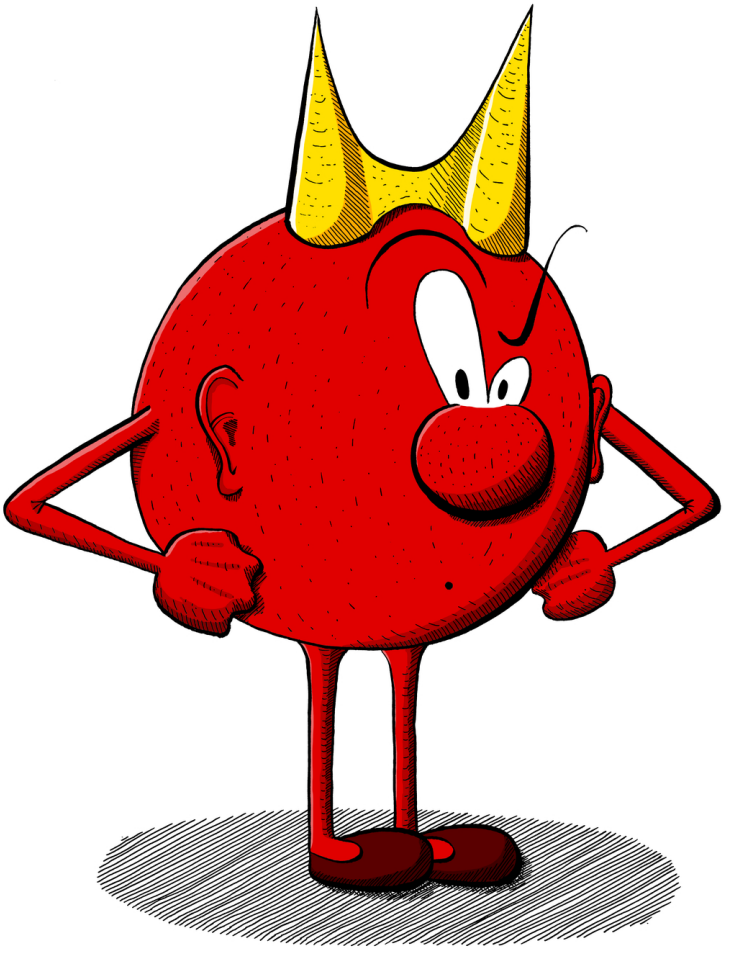




SHE SAID: "I HAVE SEEN MY DEATH."

WILHELM RÖNTGEN WANTED HUMANKIND TO IMMEDIATELY BENEFIT FROM HIS DISCOVERY AND ITS APPLICATIONS, AND HE REFUSED TO TAKE OUT PATENTS.

PIERRE AND MARIE CURIE WOULD DO THE SAME SEVERAL YEARS LATER. BUT THAT'S ANOTHER STORY.

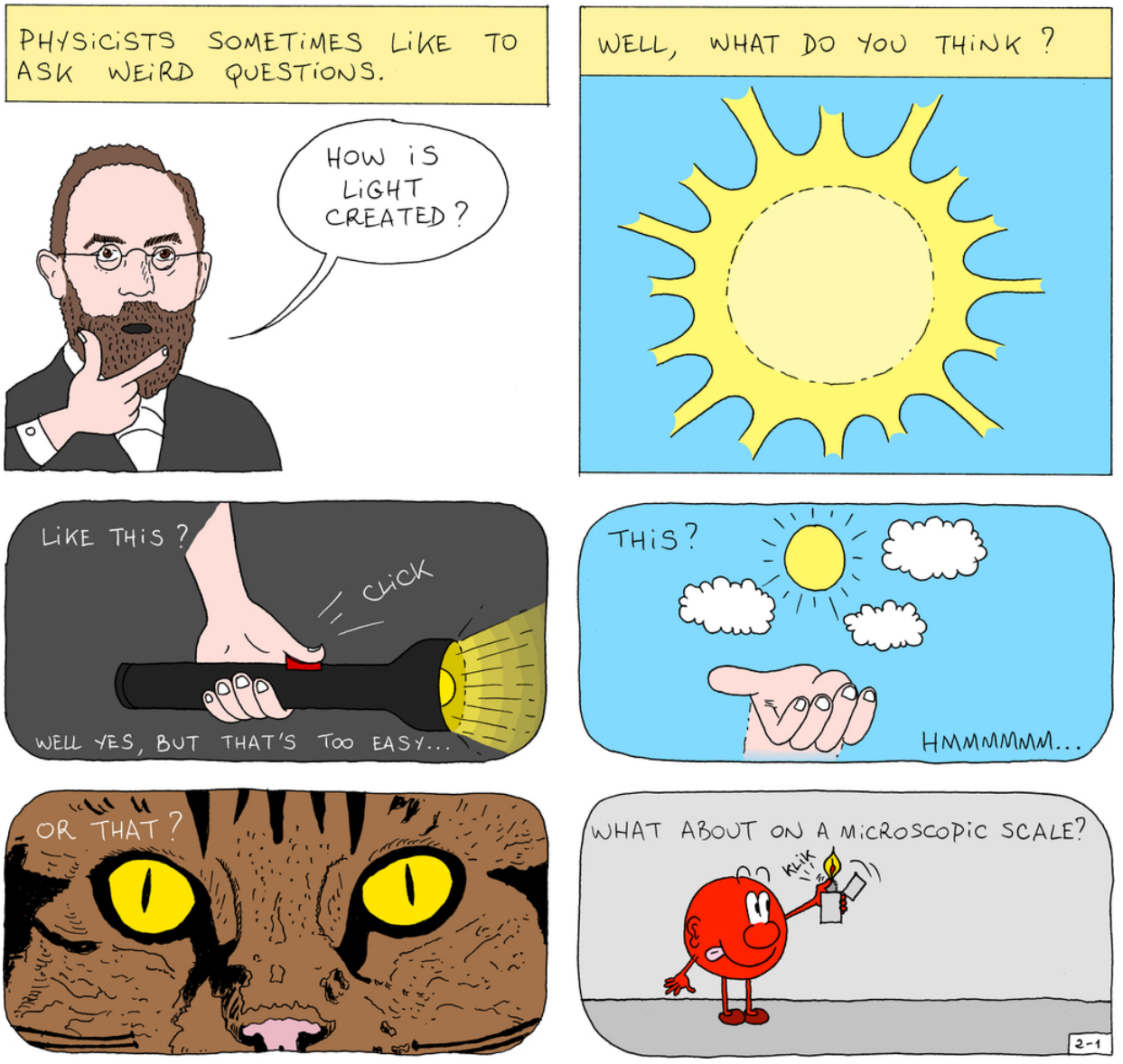


ELECTRON

1902

HENDRIK LORENTZ & PIETER ZEEMAN

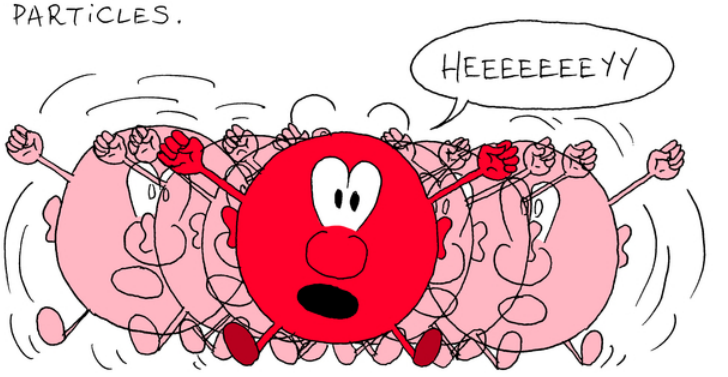
In recognition of the extraordinary service they rendered by their researches into the influence of magnetism upon radiation phenomena.



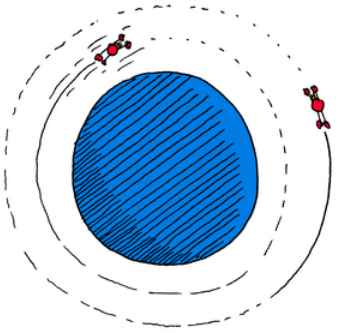
BACK IN THE LATE XIXth CENTURY, THE GOOD MR LORENTZ...

... HAD A THEORY ABOUT THAT.

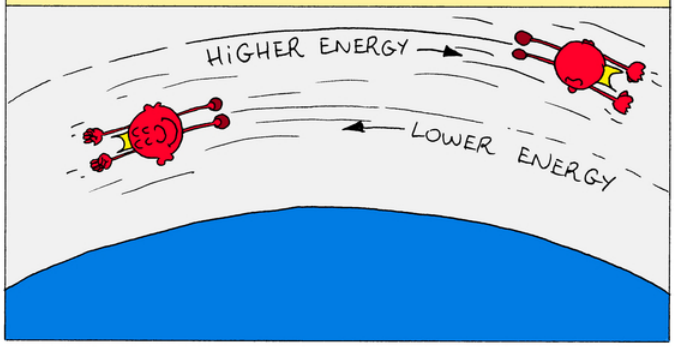
HE BELIEVED THAT LIGHT IS PRODUCED BY THE RAPID VIBRATION OF MICROSCOPIC PARTICLES.



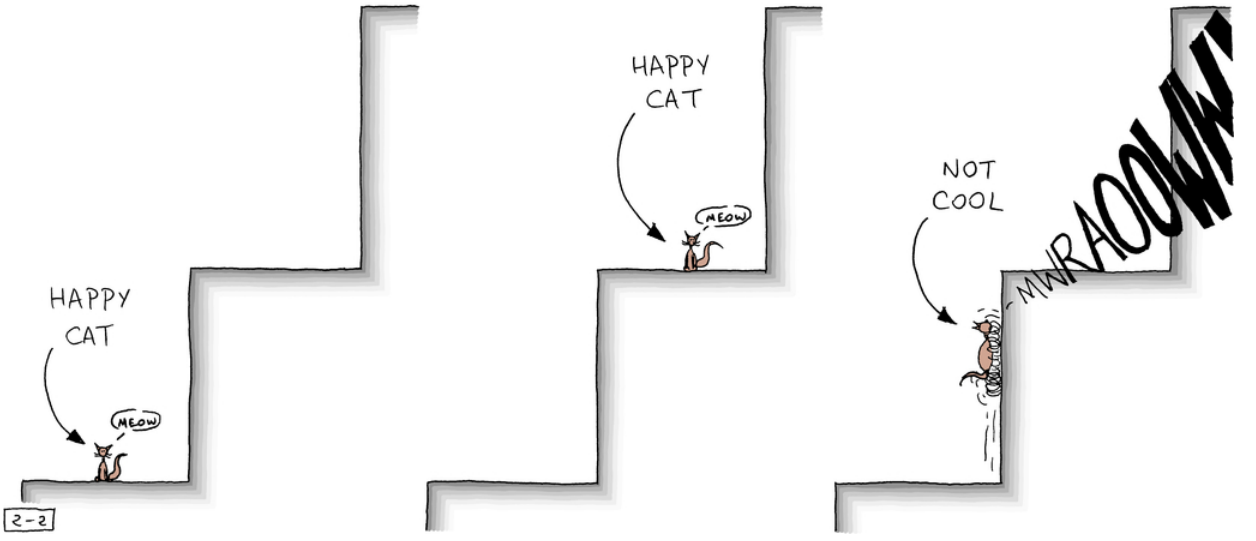
LATER SCIENTISTS HAVE DETERMINED THAT THOSE PARTICLES ARE USUALLY ELECTRONS MOVING AROUND A NUCLEUS.



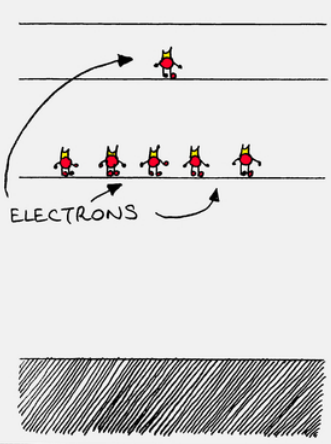
IF WE ZOOM IN, WE CAN BETTER SEE THE DIFFERENT ENERGY LEVELS. THE FARTHER AWAY FROM THE NUCLEUS, THE HIGHER THE ENERGY.



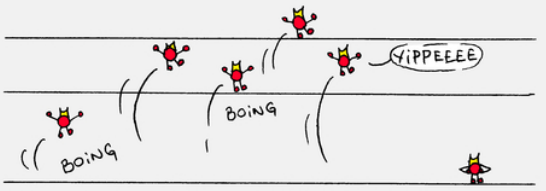
BUT THE ELECTRONS CAN ONLY EXIST AT CERTAIN PREDEFINED LEVELS AND NOTHING IN BETWEEN. A BIT LIKE A TINY CAT ON A LARGE STAIRCASE.



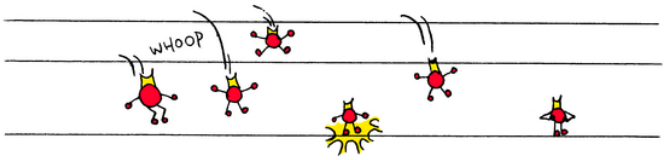
LET'S REPRESENT THIS IN A SIMPLISTIC WAY:



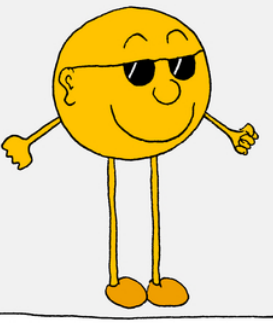
IF YOU FIND A WAY TO GIVE THESE ELECTRONS A BIG BUNCH OF ENERGY (WHICH IS EASY TO DO), YOU'LL SEE THEM JUMP TO HIGHER LEVELS.



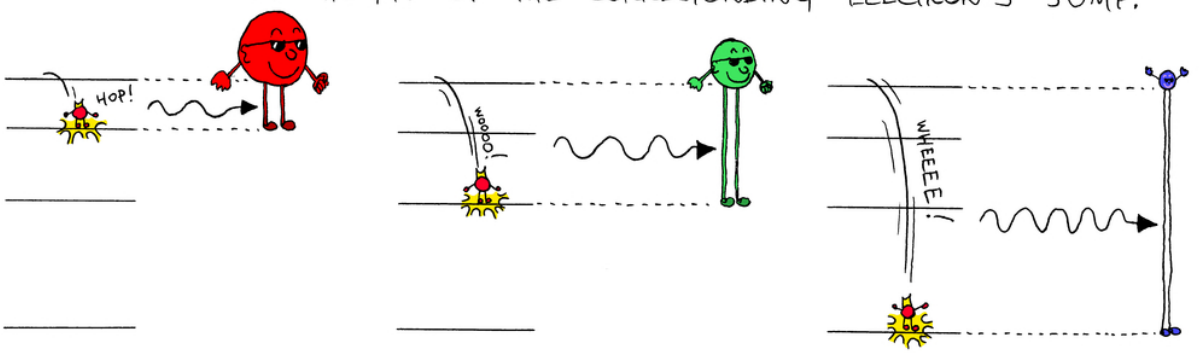
BUT AFTER A SHORT WHILE, THEY'LL GET BORED UP THERE AND WILL WANT TO GO BACK HOME. THAT MEANS THEY WILL RELEASE ENERGY AS THEY JUMP BACK DOWN.



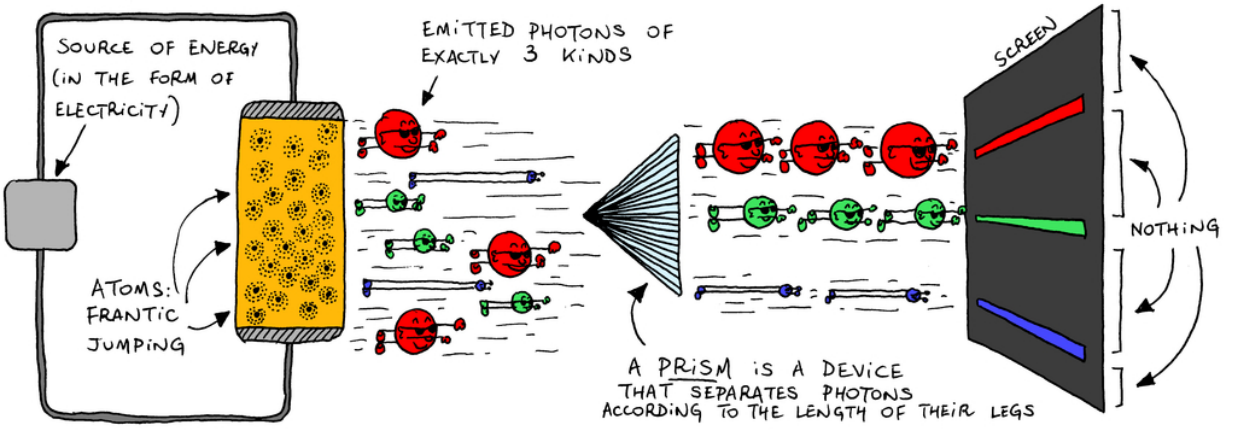
AND AS YOU MIGHT REMEMBER FROM THE PREVIOUS CHAPTER, THAT ENERGY IS RELEASED IN THE SHAPE OF A PHOTON, A TINY PACK OF LIGHT.



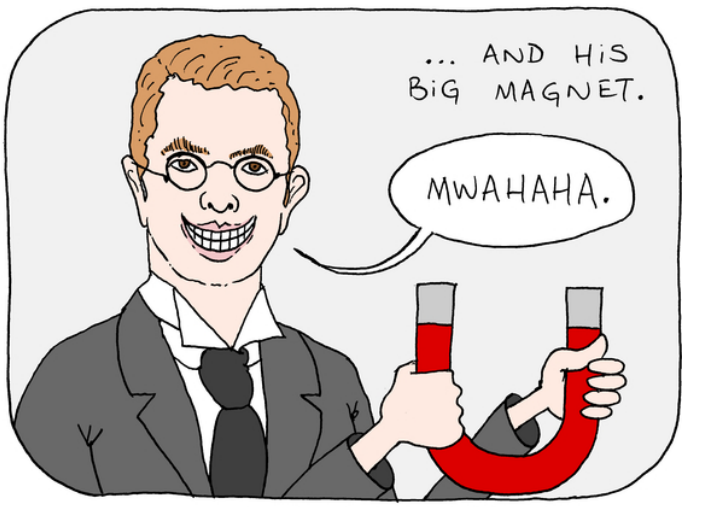
HOW LONG ARE ITS LEGS (THAT'S ALWAYS THE RELEVANT QUESTION WITH PHOTONS)? IN OTHER WORDS, HOW MUCH ENERGY DOES IT PACK? THAT DEPENDS ON THE HEIGHT OF THE CORRESPONDING ELECTRON'S JUMP.



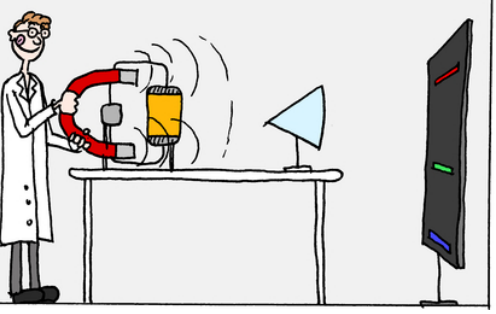
TO SEE THIS PHENOMENON IN PRACTICE, WE NEED TO GATHER A BUNCH OF IDENTICAL ATOMS (SO THAT THE PREDEFINED LEVELS FOR ELECTRONS ARE ALL THE SAME) AND PUMP SOME ENERGY INTO THAT MATERIAL TO MAKE ELECTRONS JUMP UP AND DOWN.



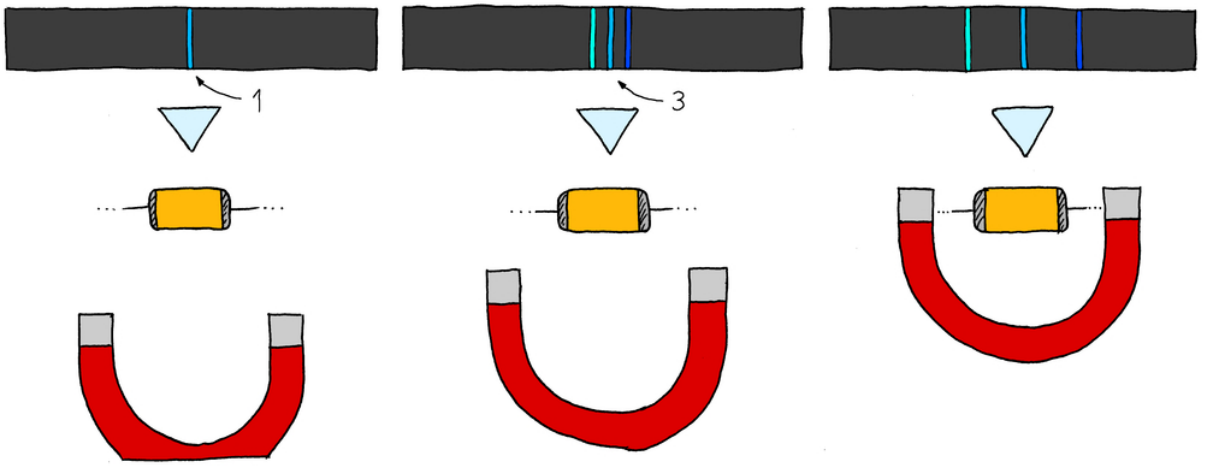
NOTE THAT WE SEE  (THAT IS CALLED A SPECTRUM) AND NOT  AS WOULD BE THE CASE IF ALL SORTS OF PHOTONS WERE EMITTED.



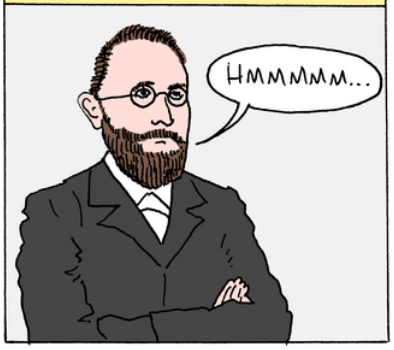
DOCTOR ZEEMAN WAS A REBELLIOUS LITTLE FELLA WHO, IN 1896, STARTED STICKING HIS MAGNET INTO THE CONTRAPTION DESCRIBED ABOVE, DESPITE HIS RESEARCH SUPERVISOR'S DIRECT ORDERS NOT TO TO SO.



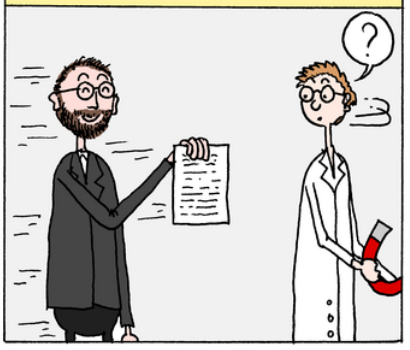
WHAT HE FOUND OUT WAS THAT WHEN THE MAGNET WAS CLOSE ENOUGH TO THE SOURCE OF THE LIGHT, THE BRIGHT LINES ON THE SCREEN WOULD START TO SPLIT.



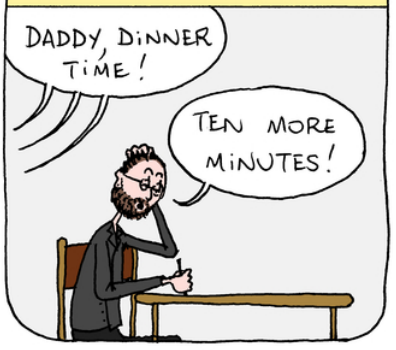
LORENTZ (WHO USED TO BE ZEEMAN'S PROFESSOR) HEARD ABOUT THESE FINDINGS ON FRIDAY 21 OCT 1896...



... AND BY THE FOLLOWING MONDAY HE HAD DRAFTED A THEORETICAL EXPLANATION THAT HE PRESENTED TO ZEEMAN.

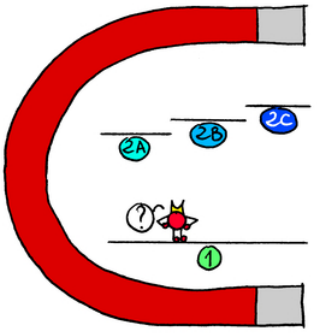


HOW MUCH TIME LORENTZ SPENT WITH HIS FAMILY DURING THAT WEEKEND IS ANYONE'S GUESS.

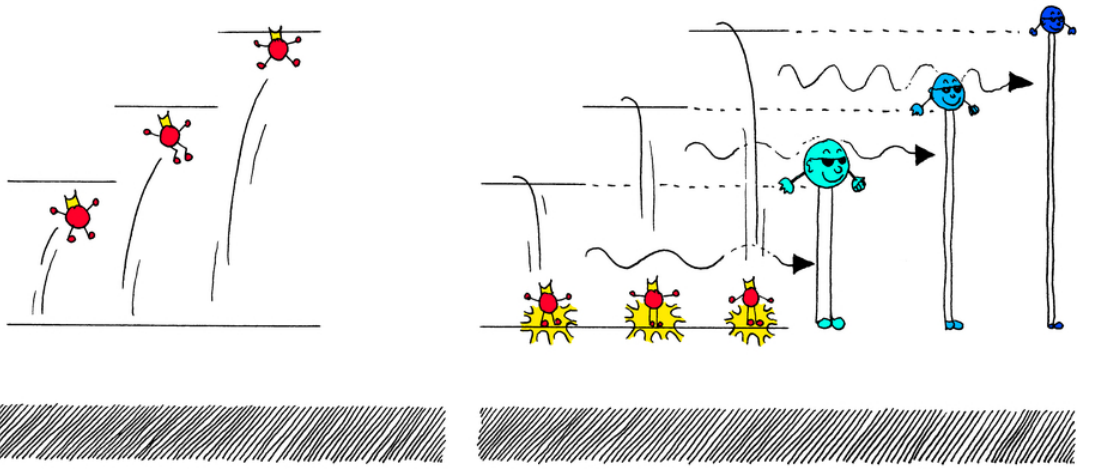


GIVEN THAT CONCEPTS SUCH AS QUANTIZED ENERGY LEVELS OR EVEN ELECTRONS WERE STILL UNKNOWN, LORENTZ'S THEORY IS NOW QUITE OUTDATED, BUT HERE IS WHAT MORE MODERN PHYSICS HAVE TO SAY ABOUT THIS.

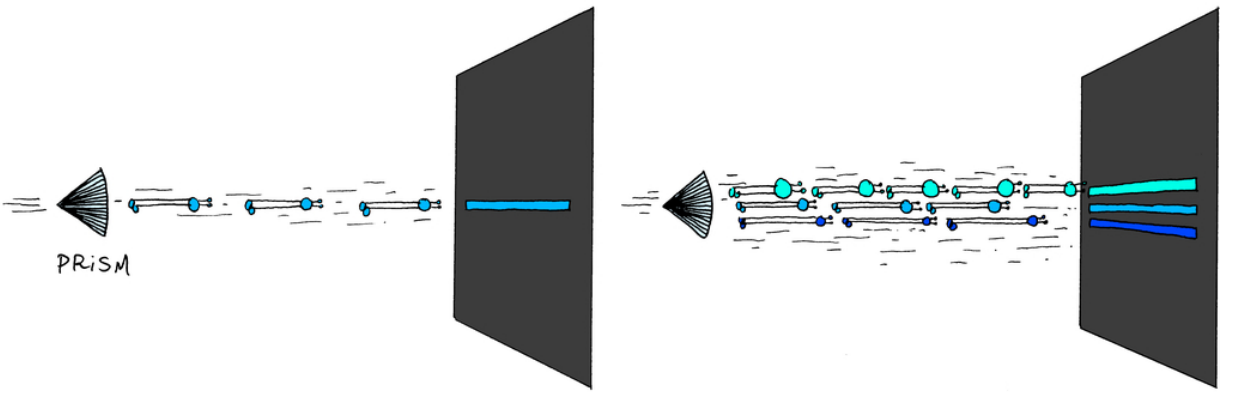
IT TURNS OUT THAT A MAGNETIC FIELD (SUCH AS THE ONE CREATED BY THE BIG MAGNET) CAN SPLIT SOME OF THESE LEVELS INTO SEVERAL SUB-LEVELS.



WHEN THAT HAPPENS, JUMPY ELECTRONS HAVE THAT MANY MORE PLACES TO HOP UP TO, AND DOWN FROM.



AND WHERE THERE USED TO BE A SINGLE LINE ON THE SCREEN, THERE ARE NOW SEVERAL.

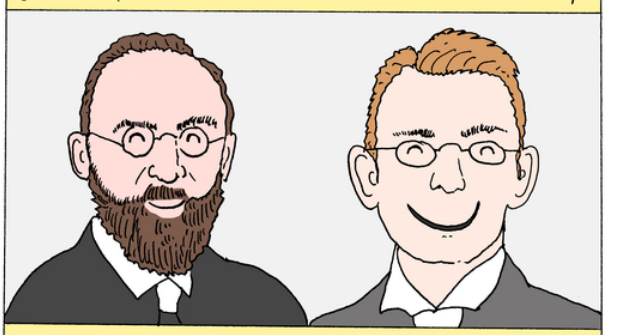


THE BAD NEWS IS THAT ZEEMAN WAS FIRED FOR DISOBEYING A DIRECT ORDER.

IMAGINE THAT HAPPENING TO YOU; HOW WOULD YOU LIKE, AS REVENGE...

2-6

...TO GET THE NOBEL PRIZE FOR PHYSICS A FEW YEARS LATER (ALONG WITH YOUR FORMER PROFESSOR)?



ONE LAUREATE IN 1901, TWO IN 1902, WILL THERE BE THREE IN 1903? THAT'S ANOTHER STORY.

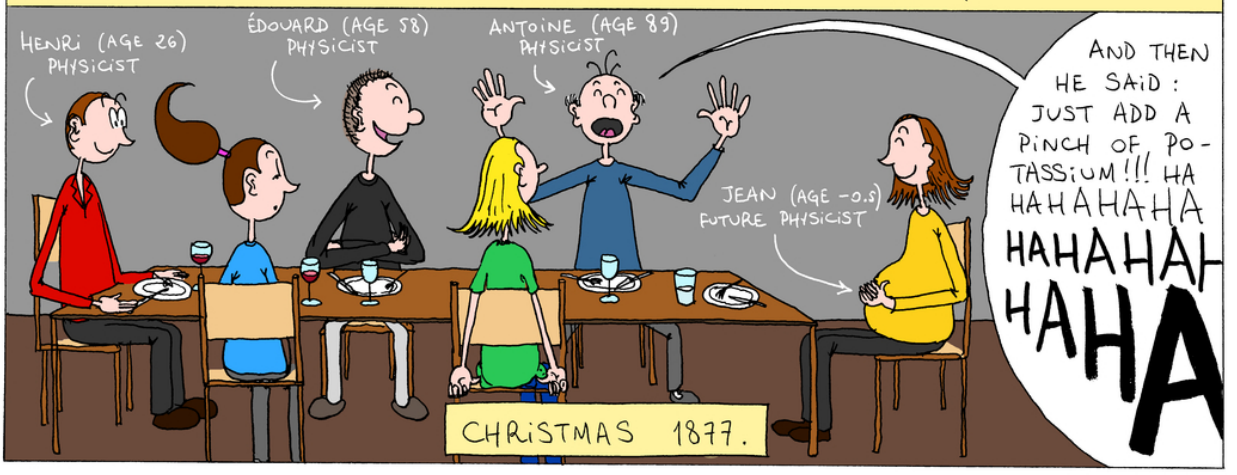
1903

HENRI BECQUEREL, PIERRE CURIE & MARIE SKŁODOWSKA CURIE

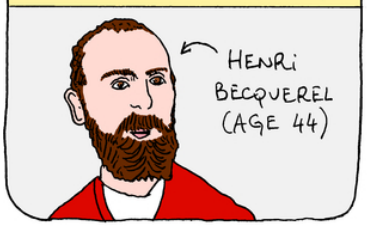
In recognition of the extraordinary services he has rendered by his discovery of spontaneous radioactivity.

In recognition of the extraordinary services they have rendered by their joint researches on the radiation phenomena discovered by Professor Henri Becquerel.

FAMILY GATHERINGS MUST HAVE BEEN FUN AT THE BECQUERELS'.

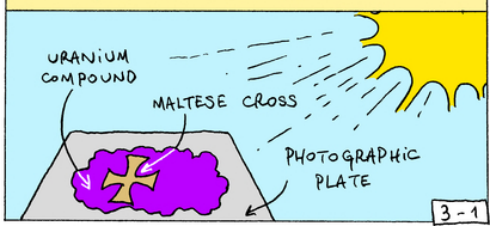


LET'S FOCUS ON THE GUY ON THE LEFT, AND FAST-FORWARD A COUPLE DECADES (1896).

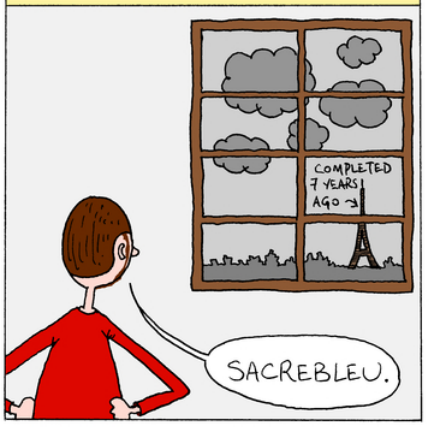


RÖNTGEN'S 1895 X-RAY DISCOVERY GOT HIM ALL EXCITED.

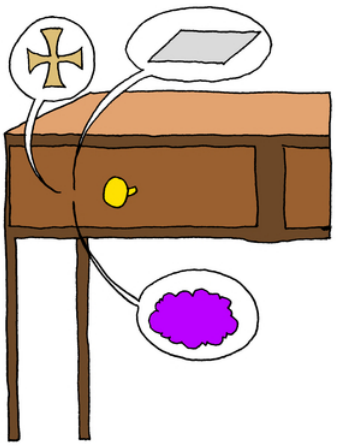
HE STARTED EXPOSING OTHER MATERIALS TO SUNLIGHT, TO SEE IF THEY, TOO, WOULD EMIT ANYTHING LIKE X-RAYS.



UNFORTUNATELY, AS M. BECQUEREL WAS TRYING TO REPRODUCE HIS EXPERIMENT, THE WEATHER IN PARIS WAS TERRIBLE...



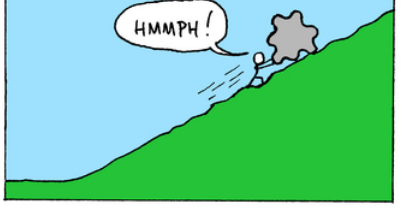
... SO HE KEPT HIS URANIUM IN A DRAWER.



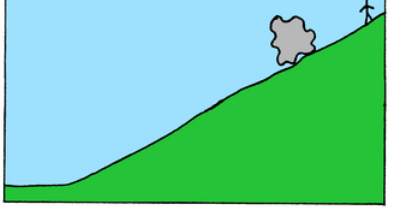
BUT WHEN HE TOOK IT OUT AGAIN, LO AND BEHOLD, THE SAMPLE HAD IMPRESSED THE PHOTOGRAPHIC PLATE, WITHOUT ANY SUNLIGHT.

BECQUEREL HAD OBSERVED WHAT IS CALLED "SPONTANEOUS RADIOACTIVITY"! IT WAS RATHER UNEXPECTED AT THE TIME THAT SOMETHING WOULD EMIT SOME SORT OF LIGHT, OR RAYS, WITHOUT HAVING BEEN "EXCITED" OR OTHERWISE TAMPERED WITH, THUS RELEASING ENERGY SEEMINGLY OUT OF NOWHERE. HOW COULD THAT BE POSSIBLE?

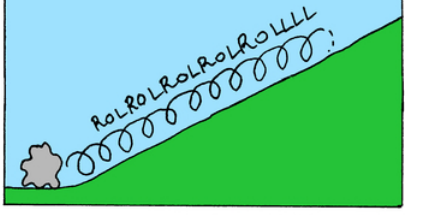
IT TURNS OUT NATURE IS A BIT OF A LAZY BUM.



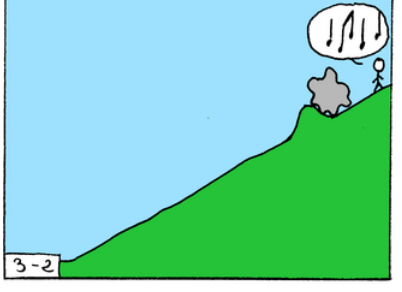
IT'S ALWAYS TRYING TO LET THINGS DROP TO THEIR STATE OF LOWEST ENERGY.



OR IN OTHER WORDS, THEIR MOST STABLE STATE.

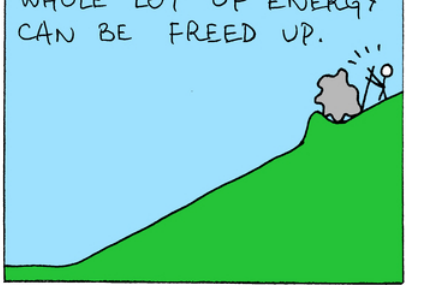


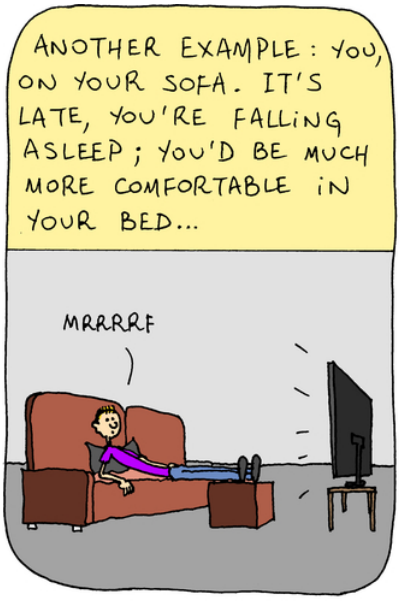
BUT WHAT HAPPENS IF THE PATH TO THE MOST STABLE STATE IS BLOCKED?

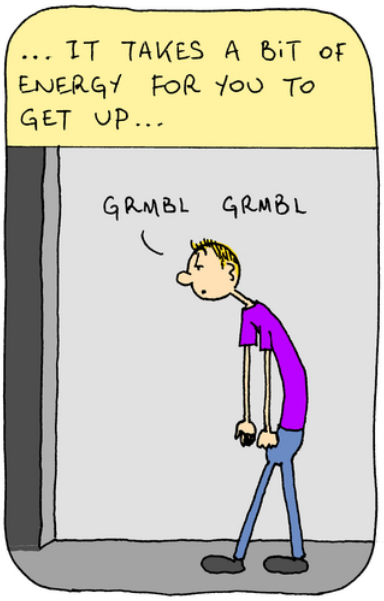


THINGS REALLY WANT TO DROP DOWN TO THAT STATE, AND THEY WILL, EVENTUALLY. BUT IT MIGHT TAKE A WHILE.

OR, A LITTLE BIT OF ENERGY MAY NEED TO BE SPENT FIRST, BEFORE A WHOLE LOT OF ENERGY CAN BE FREED UP.

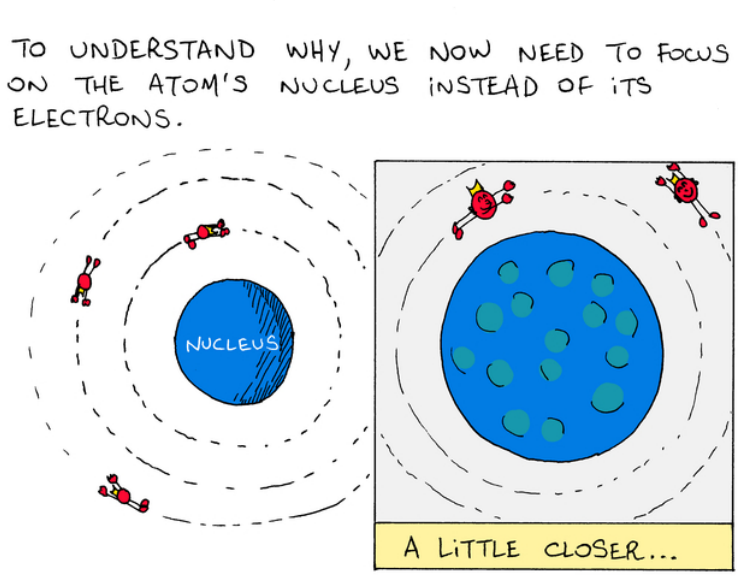


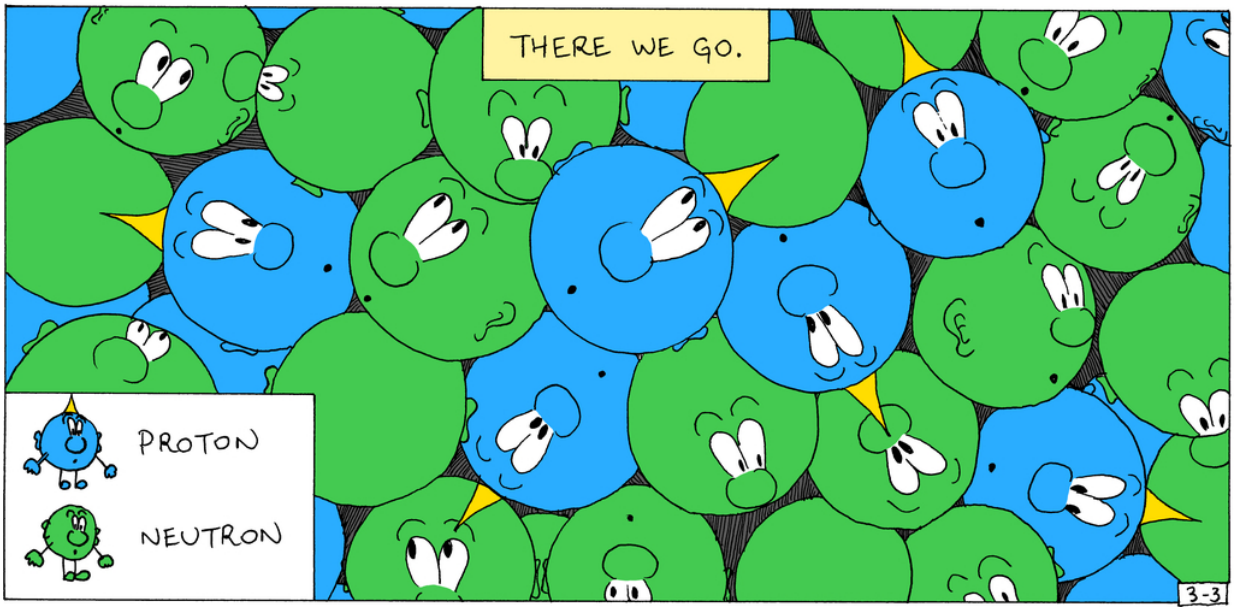

ANOTHER EXAMPLE: YOU, ON YOUR SOFA. IT'S LATE, YOU'RE FALLING ASLEEP; YOU'D BE MUCH MORE COMFORTABLE IN YOUR BED...
MRRRRF


... IT TAKES A BIT OF ENERGY FOR YOU TO GET UP...
GRMBL GRMBL

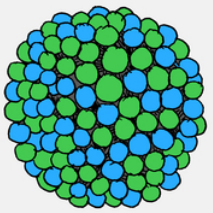

... AND EVENTUALLY REACH THIS MORE STABLE STATE FOR THE NIGHT.


YOU CAN CONSIDER A PIECE OF RADIOACTIVE MATERIAL AS A BUNCH OF ATOMS THAT HAVE FALLEN ASLEEP ON THE SOFA.
Zzzzzzz


TO UNDERSTAND WHY, WE NOW NEED TO FOCUS ON THE ATOM'S NUCLEUS INSTEAD OF ITS ELECTRONS.
NUCLEUS
A LITTLE CLOSER...


THERE WE GO.
PROTON
NEUTRON
3-3

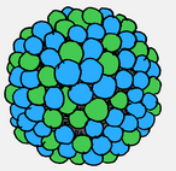
NUCLEI ARE MEANT TO HAVE (VERY ROUGHLY) THE SAME NUMBER OF PROTONS AND NEUTRONS, AND NOT TO BE TOO HUGE.

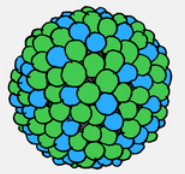


THAT'S WHEN THEY ARE MOST STABLE.

BUT IT CAN HAPPEN THAT THEY HAVE...

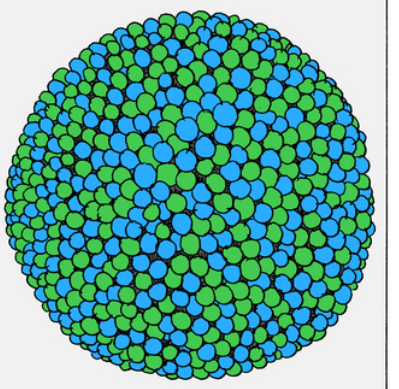
TOO MANY PROTONS



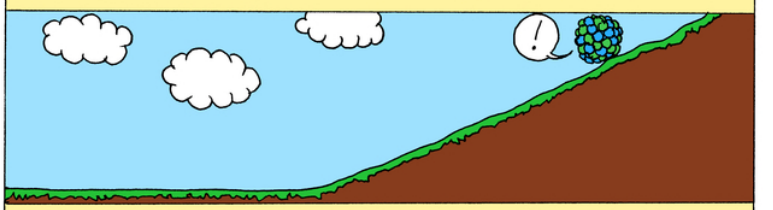


OR TOO MANY NEUTRONS

OR THAT THEY'RE JUST TOO BIG ALTOGETHER.



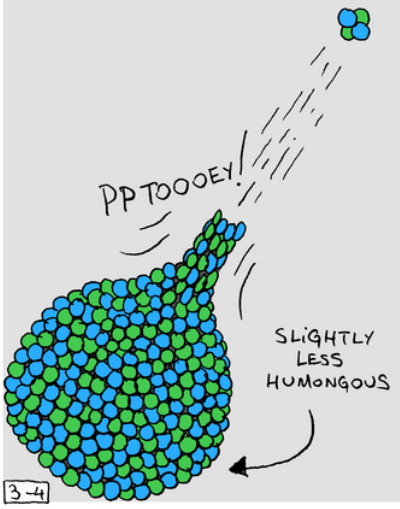
IF A NUCLEUS IS UNSTABLE, IT WILL SPONTANEOUSLY TRY TO "FIX" ITSELF.



HERE ARE 3 COMMON WAYS FOR IT TO DO SO. ALL 3 ARE CALLED "RADIOACTIVITY".

α (ALPHA)

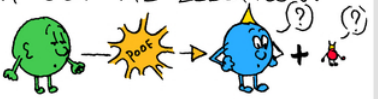
TO GET SMALLER, IT CAN SPIT OUT 2 PROTONS AND 2 NEUTRONS. THIS IS CALLED "ALPHA DECAY".

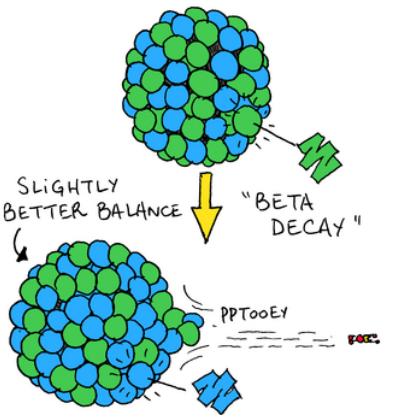


3-4

β (BETA)

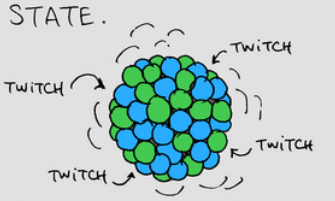
IF IT HAS TOO MANY NEUTRONS, IT CAN TRANSFORM ONE OF THEM INTO ONE PROTON + ONE ELECTRON, AND SPIT OUT THE ELECTRON.



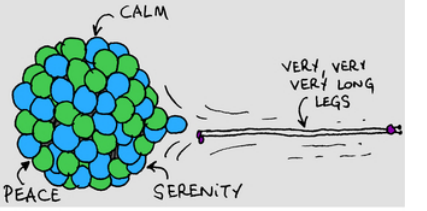


γ (GAMMA)

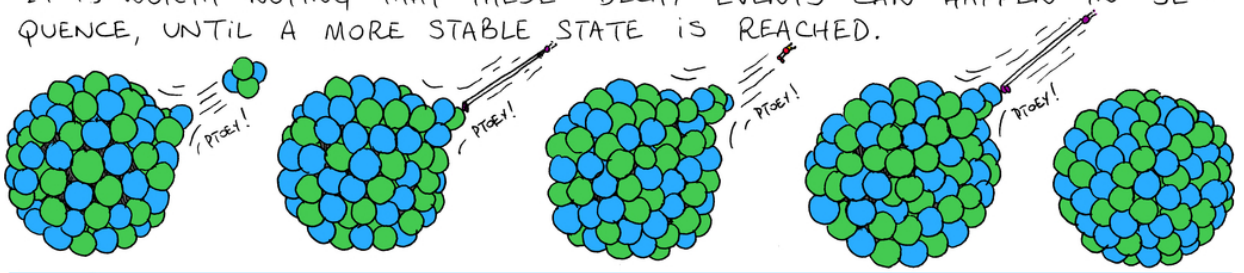
OFTEN, AFTER EITHER "α" OR "β" DECAY, THE NUCLEUS WILL STILL BE IN A BIT OF AN EXCITED STATE.

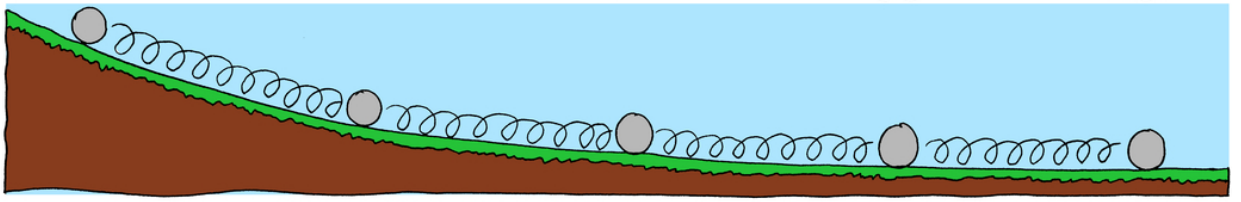


IT WILL THEN CALM BACK DOWN BY LETTING OUT SOME ENERGY = A PHOTON.

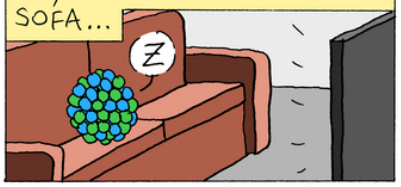


IT IS WORTH NOTING THAT THESE "DECAY" EVENTS CAN HAPPEN IN SEQUENCE, UNTIL A MORE STABLE STATE IS REACHED.



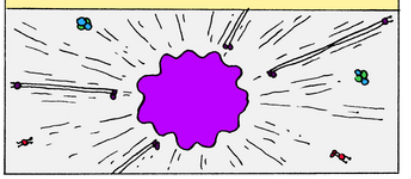


IF RADIOACTIVE ATOMS ARE SO UNSTABLE, YOU MIGHT WONDER, SURELY THERE SHOULDN'T BE ANY LEFT BY NOW? BUT REMEMBER: THEY, TOO, ARE ASLEEP ON THE SOFA...



... AND THEY ARE VERY, VERY LAZY.

BUT SINCE THERE ARE SO MANY ATOMS IN A SMALL CHUNK OF RADIOACTIVE MATERIAL, A CONSTANT FLOW OF PARTICLES IS EMITTED.



AND THAT WAS MORE THAN ENOUGH TO IMPRESS M. BECQUEREL'S PHOTOGRAPHIC PLATE.

ALSO INTERESTED IN THIS TOPIC WERE MARIE CURIE AND HER HUSBAND PIERRE WHO, IN SEARCH OF OTHER RADIOACTIVE MATERIALS, DISCOVERED TWO NEW CHEMICAL ELEMENTS.

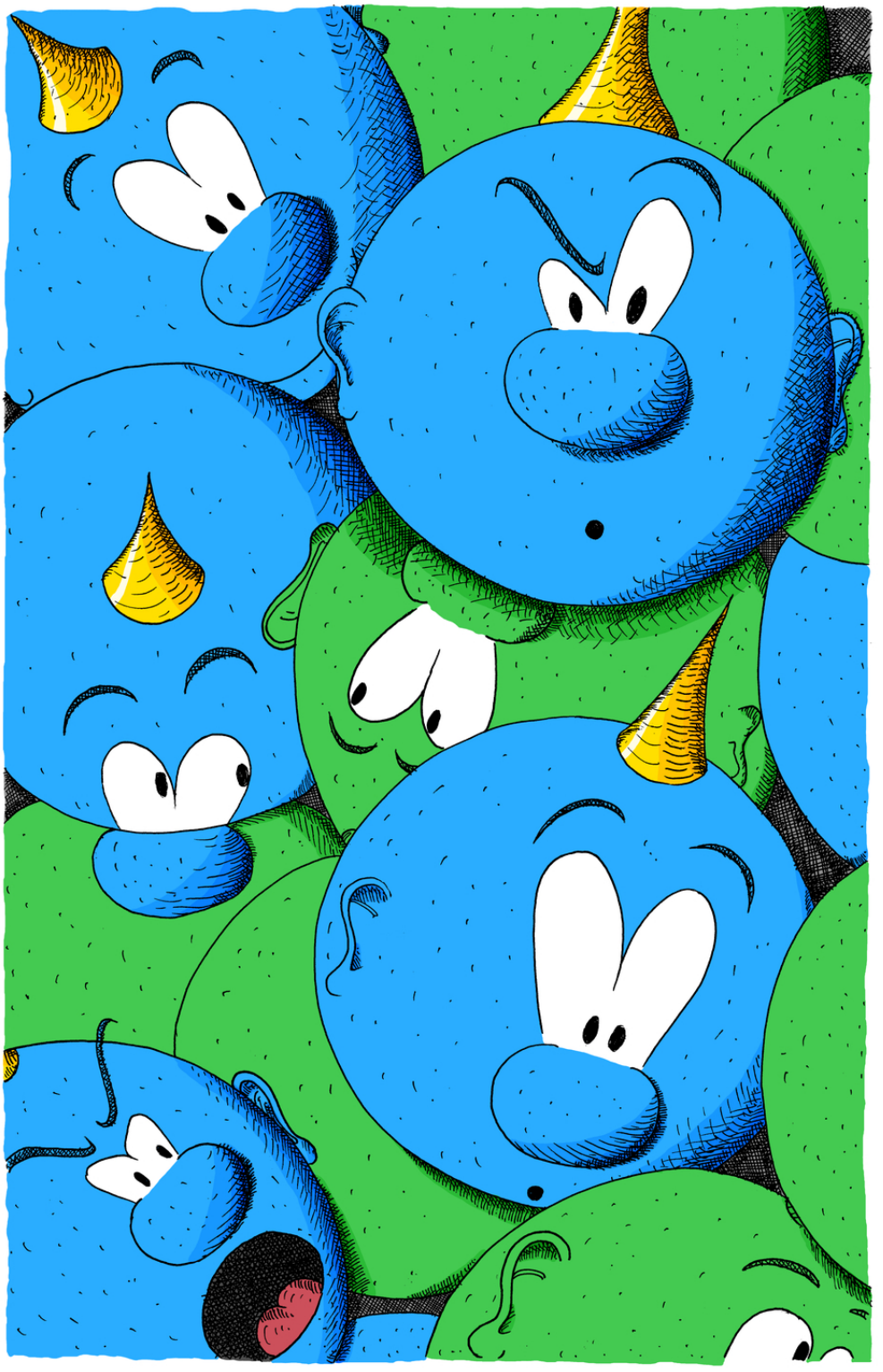
UNFORTUNATELY, THEY WERE NOT AS DILIGENT AS RÖNTGEN IN PROTECTING THEMSELVES...

... AND MARIE WOULD EVENTUALLY DIE OF THE EFFECTS OF PROLONGED RADIATION EXPOSURE, AS WOULD HER DAUGHTER AND SON-IN-LAW, BOTH PHYSICISTS.

AS FOR PIERRE, HE WAS RUN OVER BY A CAR A MERE 10 METERS AWAY FROM WHERE THE AUTHOR OF THIS BOOK SPENT HIS FIRST QUARTER CENTURY.

THE CURIES ALSO REFUSED TO TAKE OUT PATENTS.

TO THIS DAY, ALL OF THEIR LABORATORY BOOKS ARE TOO DANGEROUS TO TOUCH. EVEN MARIE'S COOKBOOKS. BUT THAT'S ANOTHER STORY.



NUCLEUS