BBC Atom: The Clash of Titans Video Notes (1/10/18)

Ludwig Boltzmann – he believed that matter cannot be infinitely divisible and that everything was made of basic building blocks 🡪 atoms (He was depressed and hanged himself 1906) He died not knowing he had been vindicated by Einstein’s paper the year before.

1850’s steam powered many machines 🡪 super important!!!! Needed to predict behavior of water and steam at high temps. Boltzmann pictured steam as atoms and created equations that predicted the behavior of steam with accuracy. THIS WAS CONTROVERSIAL. Others argued that the math was just convenient. He was condemned as an irreligious materialist by other scientists who argued that they should not simplify God’s creation as tiny particles colliding with one another.

1905 - Einstein published a paper that supported Boltzmann’s theory. Theory of Relativity paper…Paper on Nature of Light that won him a Nobel Prize… The paper relevant to this story: tiny grains of pollen danced on water!! Einstein saw that the Brownian Motion was all about atoms. The jiggling of pollen in water could settle the raging debate of atoms forever. The pollen would only jiggle if there was something causing this motion. Water must be made of tiny, atom-like particles that are themselves jiggling. No atoms 🡪 no jiggling of pollen.

EINSTEIN PROVED THAT FOR BROWNIAN MOTION TO HAPPEN, ATOMS MUST EXIST. (10:05)

1827 – Robert Brown sprinkled pollen grains in water and examined in microscope. The pollen danced furiously as though alive. Scientists soon forgot about it…for nearly 80 years this remained a scientific anomaly.

EINSTEIN CONT – His argument contained mathematics as well. He proved the dance of the pollen revealed the size of the atom. SO TINY. Single human hair is over a million atoms wide. More atoms in a single glass of water, than there are glasses of water in all the oceans in the world.

DEBATE ENDED WHETHER OR NOT THE ATOM WAS REAL OR NOT. VOLTZMANN VINDICATED!!

1910 was world’s center for atomic physics 🡪 Manchester

1911-16 Ernest Rutherford and Niels Bohr worked here and unlikely collaborators

Rutherford – grew up on a farm in New Zealand, loved technology, profound intuition, experimenter

Bohr – grew up wealthy, virtually aristocrat, ultimate theoretician and abstract mathematics, pen and paper/chalk and chalkboard, LOGIC

Genuine revolutionists!

1907 – Rutherford took over the Physics Dept in Manchester. Period of great discoveries (10 years ago, X rays discovered and then electrons discovered a couple years after that, 1896 Uranium emitted radioactivity)

Rutherford was obsessed with radioactivity. His assistants were Geiger (Geiger counter) and Ernest Marsden

1909 – Gold leaf experiment – Radium is a source of alpha rays. With a phosphorescent plate, count the particles that pass through the gold leaf. Nothing unusual found. THEN Rutherford told them to watch for alpha particles bouncing back off the leaf.   
Geiger saw 1 in 8,000 alpha particles bounced back!!!!!! Rutherford knew he struck physics gold! This was the discovery of a NUCLEUS!!! He calculated the nucleus was 10,000 x smaller than the atom itself. Electrons surround the nucleus. Most of the atom is empty space. If the nucleus were the size of a soccer ball, then the electrons would be in orbit a half mile away.

*Why don’t electrons lose energy and crash into the nucleus? They didn’t obey the laws of physics.*

Niels Bohr moved to Manchester University with Rutherford. He made it his mission to explain the empty space in an atom. He studied light. Most substances glow with their own distinctive colors when heated. The colors associated with diff substances is called spectra.

Bohr described the atom like a building with nucleus on the ground. Electrons cannot live in between floors, but they can jump from floor to floor. When an electron jumps from a higher floor to a lower floor will give off light…diff color light with diff size jumps.

*Why would the electrons behave like they were on floors of a building and why would they jump?*

Conflict between the two generations of scientists was inevitable!!

**Traditionalists** – Einstein hated Bohr’s ideas!!! Schrodinger

**Radicals** – Bohr (Rutherford’s side), Pauli, Heisenburg

1916 – Bohr went back to Copenhagen a celebrity and was able to gain funding for research. Niels Bohr Institute.

1924 – Radicals revealed a new theory based on quantum jumps 🡪 **Wolfgang Pauli** turned quantum jumps idea and came up with the exclusion principle. “Every atom is made of the same components, so how do we have so many different elements with different properties?”

Each floor can only accommodate a fixed number of electrons!! So a diff number of electrons changes the shape of the atom!!!   
 Einstein hated this!!!!!!

1925 – Letter on Einstein’s desk from deBrois…radio waves could describe the atom? No strange quantum jumps

1925 - Schrodinger – philosopher, romantic, cool, suave, sophisticated – took DeBrois’s idea a step further…cloud-like wave and a new equation Schrodinger’s wave equation. Wave function described the behavior of the subatomic world (he claimed!!!) Couldn’t explain Bohr’s quantum jumps

Summer of 1925 Heisenberg - mountain climber and pianist, atom was so unique and unusual and shouldn’t be described as a wave or a building. He didn’t like a picture of the atom. He believed human attempts to visualize the atom would fail. He wanted to describe using pure mathematics alone. To describe properties of atoms (where an electron is and how fast it is moving) he would need new math. Matrix mechanics was born. He could predict electron behavior. Einstein hated this!!!

1926 in Munich - Schrodinger presented his new wave mechanics to a packed audience. Heisenberg came to call him out. Heisenberg is booed as the audience has Schrodinger’s back. H leaves sad and their backs were against the wall.

Heisenberg and Bohr continued to work…

**H said it is unknowable to know an electron’s position and the speed at the same time. Heisenberg’s uncertainty principle!!!! They behave like particles and waves. Not looking at an atom, it looks like a spread out wave. When you look where it is, it behaves like a particle but when it’s not moving it appears like a wave.**

1927 – Conference in Brussels….If Bohr and Heisenberg are correct, they could lead a scientific revolution. Bohr and Einstein were rivals… BOHR was victorious! Copenhagen interpretation was Bohr’s side of the atom.

