Advanced Transition Metal Chemistry – Periodic Table

Prof. M. S. Balakrishna
Department of Chemistry
Indian Institute of Technology – Bombay

Lecture – 2
It is all About the Periodic Table

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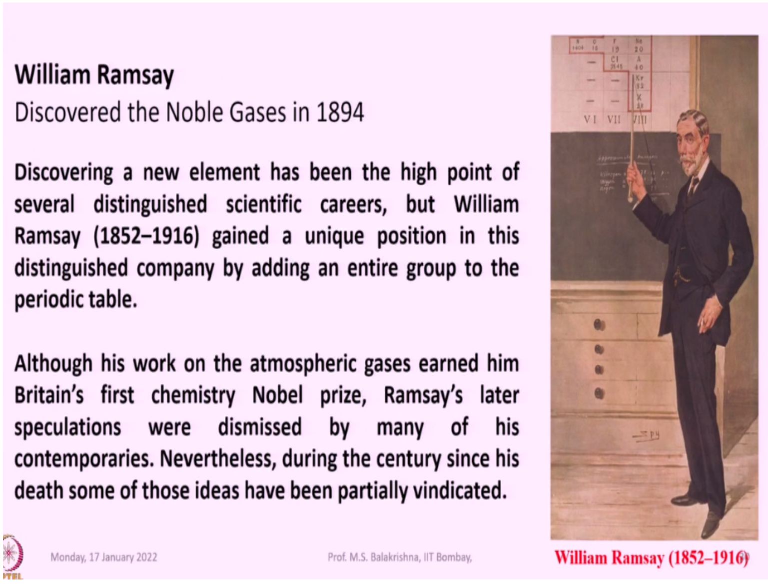

Welcome to my second lecture on advanced transition metal chemistry. In my previous lecture, I was discussing about the history of periodic table. Let me continue from where I had stopped. Let me tell you a little bit about William Ramsay who discovered all noble gases and published the results in 1894. So, after the periodic table was published by Mendeleev, discovering a new element has been the high point of several distinguished scientific areas.

But William Ramsay who lived from 1852 to 1916 gained a unique position in this distinguished company by adding an entire group to the periodic table. That means the group 18 elements, all inert gases were discovered because of very painstaking systematic work carried out by William Ramsay. Although his work on the atmospheric gases earned him Britain's first chemistry Nobel Prize, Ramsay's later speculations were dismissed by many of his contemporaries. Nevertheless, during the century since his death some of those ideas have been partially vindicated.

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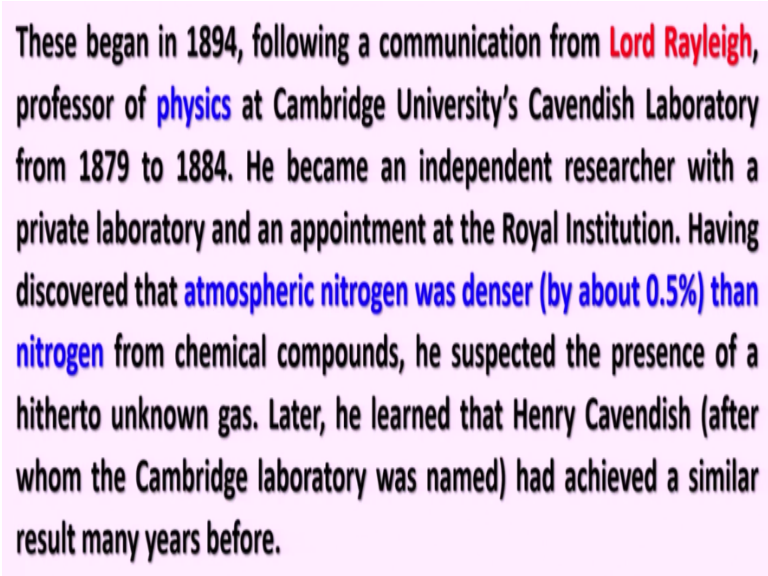

So, these began in 1894 following a communication from Lord Rayleigh, professor of physics at Cambridge University's Cavendish Laboratory from 1879 to 1884. He became an independent researcher with a private laboratory and an appointment at Royal Institution. So having discovered that atmospheric nitrogen was denser by about very minute 0.5% than nitrogen from chemical compounds.

So that means when you separate nitrogen from atmosphere and look into its density and when you generate nitrogen in the laboratory, the nitrogen that was generated in the laboratory was less denser by 0.5%. So, he suspected the presence of a hitherto unknown gas. That means the atmospheric nitrogen, so called isolated, taking away air, has some other component, was identified during that time.

So later, he learned that Henry Cavendish after whom the Cambridge laboratory was named had achieved a similar result many years before. So, we have to appreciate their analytical skills about identifying even very minute difference in the density.

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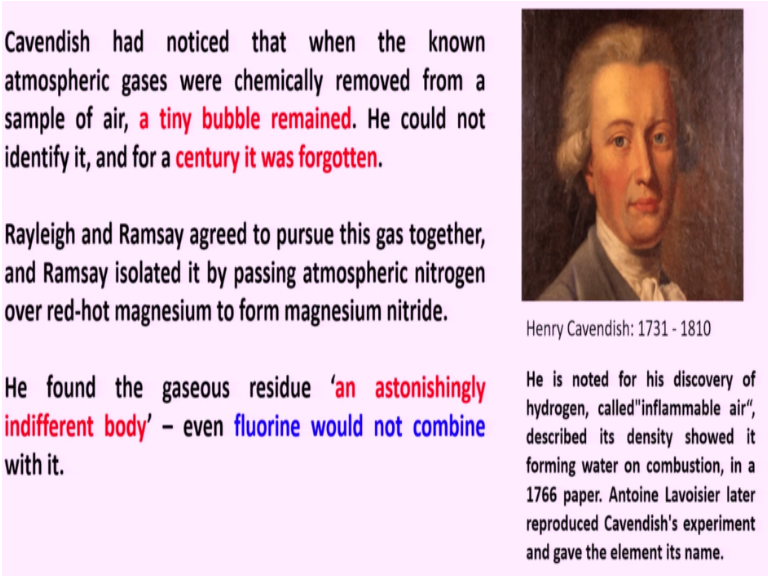

Cavendish had noticed that when the known atmospheric gases were chemically removed from a sample of air, a tiny bubble remained. He could not identify it and for a century it was forgotten. So that means he made that beautiful observation almost 100 years before Ramsay started looking into it. So, Rayleigh and Ramsay agreed to pursue this gas together and Ramsay isolated it by passing atmospheric nitrogen over red hot magnesium to form magnesium nitride.

First oxygen was separated from atmospheric air, and then the atmospheric nitrogen was passed over red hot magnesium; the magnesium forms magnesium nitride. And after completion of the formation of magnesium nitride, he found the gaseous residue, an astonishingly indifferent body, even fluorine would not combine with it. So that means a fraction of very small or minute quantity of gas that was left after completely consuming nitrogen by treating that with red hot magnesium to form magnesium nitride, was found to be inert compared to fluorine.

Why he said fluorine ~~is~~? Fluorine is the most reactive element and it can combine with literally any element that is present in the periodic table. That is the reason he says it is an astonishingly indifferent body and even fluorine would not combine with it. He is noted, Henry Cavendish is noted for his discovery of hydrogen; called inflammable air, described its density, showed it forming water on combustion in a 1766 paper. So, Antoine Lavoisier later reproduced Cavendish's experiments and gave the element its name.

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In British Association meeting, Rayleigh and Ramsay announced the discovery of a new element to the Royal Society in January 1895. **They named it – argon – derived from the Greek word for 'idle'.**

Although spectroscopic analysis by **William Crookes** confirmed that the new gas had a distinctive line-pattern, some critics disputed its elementary status. Ramsay ignored them, and was soon pursuing another mystery gas.

In British Association meeting, both Rayleigh and Ramsay announced the discovery of new element to the Royal Society in January 1895. They named it argon, derived from the Greek word for idle. Although spectroscopic analysis by William Crookes confirmed that the new gas had a distinctive line pattern, some critics disputed its elementary status. Ramsay ignored them and was soon pursuing another mystery gas. So once after the discovery of argon, he did not give up, he continued working to find out other missing gases.

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Chemists, know your place! Referred to Inert Gases

In February 1895 the British mineralogist **Henry Miers** alerted **Ramsay** to an unusual property of cleveite (a mineral consisting mainly of UO_2). William Hillebrand – a chemist with the United States Geological Survey – had noticed that heating cleveite with H_2SO_4 generated an unreactive gas, which he presumed was nitrogen. On learning this, Ramsay carefully finished the experiments he was working on, obtained a sample of cleveite from a London mineral dealer for **three shillings and six pence (14.5 pounds now)** and soon he had a sample of Hillebrand's gas.

So, chemists know your place, referred to inert gases. This is some sort of statement made at that time. So in February 1895, the British mineralogist Henry Miers alerted Ramsay to an important unusual property of cleveite, a mineral consisting mainly of uranium oxide. So William Hillebrand, a chemist with the United States Geology Survey, had noticed that heating cleveite with sulfuric acid generated an unreactive gas which he presumed was nitrogen.

On learning this, Ramsay carefully finished the experiments he was working on, obtained a sample of cleveite from a London mineral dealer for 3 shillings and 6 pence, that means ~~five~~ 14.5 pounds ~~,~~ now, and soon he had a sample of Hillebrand’s gas, this is called Hillebrand’s gas.

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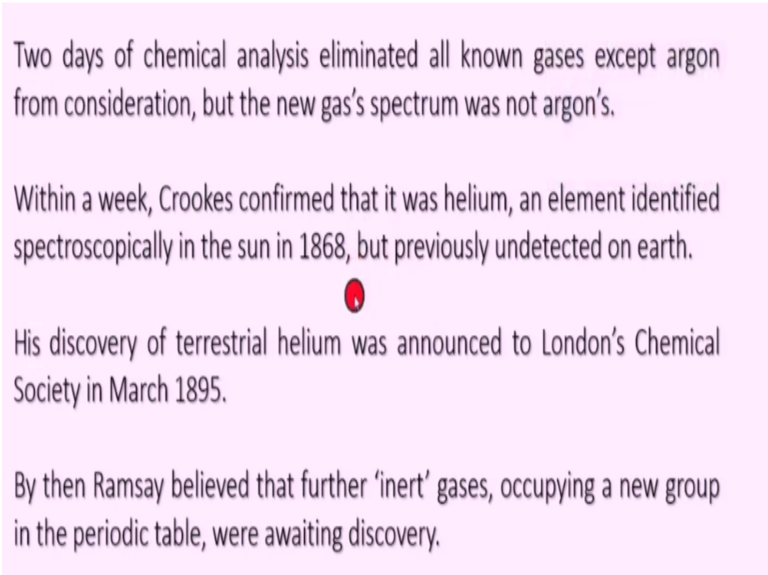

Two days of chemical analysis eliminated all known gases except argon from consideration, but the new gas’s spectrum was not argon’s. So that means whatever the gas he obtained, he eliminated all other gases except argon for consideration and the new gas he found showed a different spectrum from argon. So within a week, Crookes confirmed that it was helium, an element identified spectroscopically in the sun in 1868, but previously undetected on earth.

His discovery of terrestrial helium was announced to London's Chemical Society in March 1895. So Ramsay's discovery of terrestrial helium was announced to London's Chemical Society in March 1895. By then, Ramsay believed that further inert gases occupying a new group in the periodic table were awaiting discovery.

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James Dewar opposed Ramsay's concept of a class of inert gases
His ideas were loudly opposed by Dewar, professor of chemistry at London's Royal Institution.
Anonymous attacks on Ramsay's work also appeared in *Chemical News*– probably written by Dewar's friend **Henry Armstrong**.
Rayleigh soon abandoned this chemists' quarrel and returned to the more gentlemanly world of physics where – as he later commented – 'second-rate men seem to know their place'. Ramsay, however, battled on.

So James Dewar, another contemporary of Ramsay, opposed Ramsay's concept of a class of inert gases. His ideas were loudly opposed by Dewar, a professor of chemistry at London's Royal Institution. So anonymous attacks on Ramsay's work also appeared in chemical news, probably written by Dewar's friend Henry Armstrong.

So Rayleigh soon abandoned this chemist's quarrel and return to the more gentlemanly world of physics where as he later commented second rate men seems to know their place. Ramsay however battled on. That means Rayleigh after seeing unworthy criticism he gave up and he got back to physics research, but however Ramsay continued.

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One obstacle to argon's acceptance as an element was its apparent atomic weight. Its vapour density (relative to that of hydrogen) was 19.9, which indicated a molecular weight of 39.8.
But the ratio of its two specific heats – at constant pressure, and at constant volume – implied that the gas was monatomic.
This gave argon an At. Wt. higher than its neighbour, potassium (39.0983), and hence a somewhat incongruous position in the periodic table.

One obstacle to argon's acceptance as an element was its apparent atomic weight. Its vapour density, relative to that of hydrogen I am talking about, was 19.9 which indicated a molecular weight of 39.8. So that means probably it is very similar to diatomic species, but the ratio of its two specific heats at constant pressure and at constant volume implied that the gas was monatomic. So, this gave argon ~~in~~ an atomic weight higher than its neighbouring potassium, that is potassium atomic weight is to be precise 39.0983, and hence a somewhat incongruous position in the periodic table.

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Two other pairs of adjacent elements – tellurium and iodine, and cobalt and nickel – were similarly misplaced in the table.
Many chemists believed that their published atomic weights were erroneous, but Ramsay's critics rejected this explanation for the argon–potassium anomaly.
Instead, they argued that the new gas was an allotrope of nitrogen, with the formula N_3.

Two decades later, Frederick Soddy's introduction of the concept of an isotope would explain the anomalous atomic weights, and Henry Moseley's determination of atomic numbers would rationalise the periodic table. But meanwhile, the onus remained on Ramsay to justify his claims.

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To confirm the status of argon and helium – and to isolate any further atmospheric gases – Ramsay needed large-scale facilities for liquefying and fractionally distilling air. But Britain's leading expert in this field was his opponent **Dewar**, inventor of the vacuum–jacketed container still known as the 'Dewar flask'. Instead, Ramsay turned to **William Hampson** (with whom Dewar was also in dispute).

Hampson was an Oxford classics graduate who trained as a barrister before emerging as a scientist. In 1895 he patented an innovative process for liquefying gases and licensed it to Brinn's Oxygen Company (later to become the industrial giant British Oxygen, now BOC). Hampson provided advice, and some liquid air, but Ramsay and his assistant Morris Travers built their own distillation apparatus – much of it improvised from recycled equipment.

To confirm the status of argon and helium, and to isolate any further atmospheric gases, Ramsay needed large scale facilities for liquefying and fractionally distilling air. But Britain's leading expert on this field was his opponent Dewar, inventor of vacuum-jacketed container still known as the Dewar flask. Whatever we are using today are all invented by Dewar vacuum flask.

So, instead Ramsay turned to William Hampson, with whom Dewar also has ~~dispute~~ dispute, to get that facility of liquefying larger quantity and distilling air. Hampson was an Oxford classics graduate who trained as a barrister before emerging as a scientist. In 1895, he patented an innovative process for liquefying gases and licensed it to Brinn's Oxygen company later to become the industrial giant British Oxygen. So, now it is called BOC.

So, Hampson provided advice and some liquid air, but Ramsay and his assistant Morris Travers built their own distillation apparatus, much of it improvised from recycled equipment.

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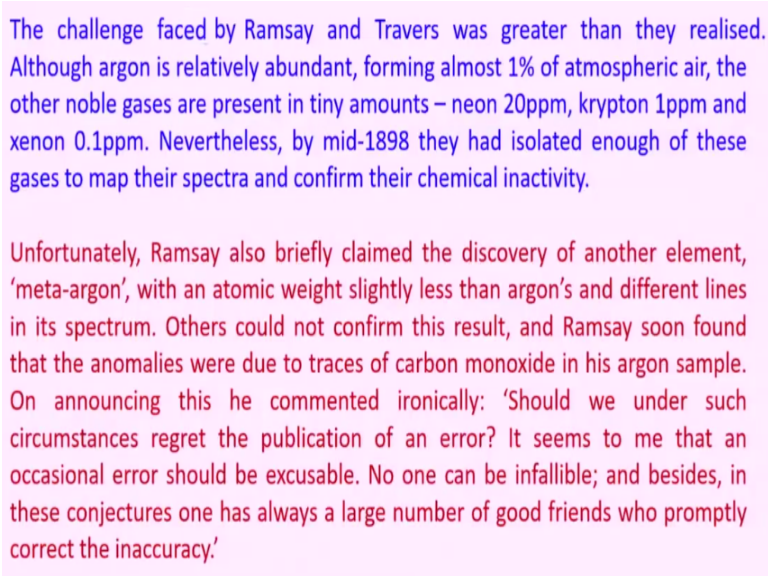

The challenge facing Ramsay and Travers was greater than they realized. Although argon is relatively abundant, forming almost 1% of atmospheric air, the other noble gases are present in very tiny amounts, neon about 20 parts per million, krypton 1 parts per million and xenon 0.1 ppm. So nevertheless, by mid 1898, they had isolated enough of these gases to map their spectra and confirm their chemical inactivity, and also their chemical identity.

Unfortunately, Ramsay also briefly claimed the discovery of another element meta-argon with an atomic weight slightly less than argon's and the different lines in its spectrum. So, others could not confirm this result and Ramsay soon found that anomalies were due to traces of carbon monoxide in his argon sample. So, announcing this he commented ironically, should we under such circumstances regret the publication of an error?

It seems to me that an occasional error should be excusable. So when you are working with great deed, identifying new elements, I think such small errors can be neglected, so no one can be infallible and besides in these conjectures one has always a large number of good friends who promptly correct the inaccuracy. So, this is where healthy criticism and critical evaluation of research plays a major role.

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During this period, Ernest Rutherford and Pierre and Marie Curie – had found that some radioactive elements released a heavy gas, which Rutherford called 'emanation'. Since it appeared to belong to the noble gas family, it naturally attracted Ramsay's attention.

This radioactive gas took different forms–'thorium emanation', 'radium emanation' and 'actinium emanation' –which were eventually identified as isotopes of the same element. Radium emanation –later simply called 'radon' – was the longest-lived, with a half-life of 3.8 days.

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Radium emanation, later simply called radon, was the longest lived with a half-life of 3.8 days. In 1903, Ramsay joined with Rutherford's former collaborator Frederick Soddy to study it. By the time what happened, Ramsay's co-worker Travers has to leave ~~to~~ for India to become director of Indian Institute of Science.

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They found that a sealed container of radon, if left standing for a time, eventually generated the characteristic spectrum lines of helium. This important result supported Rutherford's suggestion that the positively charged alpha particles emitted by **radon** (and other radioactive elements) were actually the nuclei of helium atoms. But after Soddy moved on to Glasgow University in 1904, Ramsay's later work on radioactivity proved less fruitful.

Ramsay hoped that bombarding other elements with radon's alpha particles might change their chemical identity. His eagerness led him to announce some spurious 'discoveries'– for example, in 1907 he claimed that electrolysing a copper salt dissolved in water previously exposed to radon converted the copper into lithium. Other experimenters could not replicate these results, and physicists (including Rutherford) dismissed them as impossible on theoretical grounds.

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At that time Ramsay and Rutherford found that a sealed container of radon, if left standing for a time, eventually generated the characteristic spectrum lines of helium. So, this important result supported Rutherford's suggestion that the positively charged alpha-particles emitted by radon were actually the nuclei of helium atoms $^{2}He_{4}$. But after Soddy moved on to Glasgow University in 1904 Ramsay's later work on radioactivity proved less fruitful.

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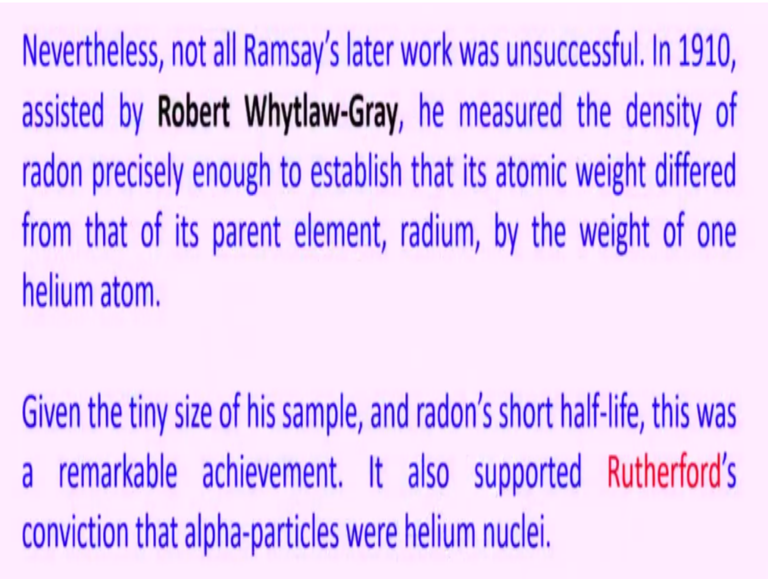

However, Ramsay's later work was unsuccessful. In 1910 assisted by Robert Whytlaw-Gray, he measured the density of radon precisely enough to establish that its atomic weight differed from that of its parent element radium by the weight of one helium atom. So given the tiny size of his sample and radon's short half-life, this was a remarkable achievement. It also supported Rutherford's ~~conviction~~ conclusion that alpha-particles were helium nuclei.

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Henry Moseley ~1913

- Determined the atomic number of each of the elements
- He modified the 'Periodic Law' to read that the properties of the elements vary periodically with their atomic numbers
- 1914:Predicted that there were 3 unknown elements between aluminum and gold
- Concluded there were only 92 elements up to and including uranium

When we talk about the periodic table and properties that depicts today in understanding chemistry, it is very appropriate to talk about Henry Moseley. So, Henry Moseley determined the atomic number of each of the elements. He modified the Periodic Law to read the properties of the elements vary periodically with their atomic numbers that means physical and chemical properties of elements are the periodic functions of their atomic numbers was what the information provided from the extensive work carried out by Henry Moseley. In 1914, he predicted that there were 3 unknown elements between aluminum and gold and he concluded that there were only 92 elements up to and including uranium.

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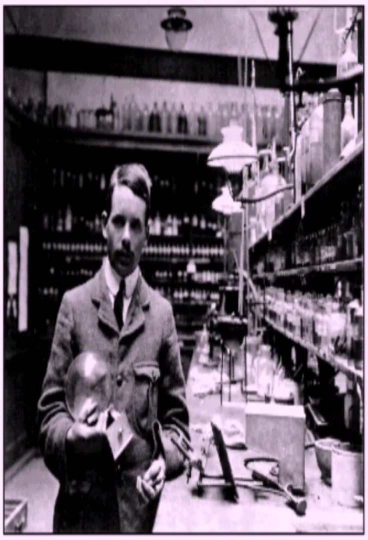
Henry Moseley 1887 - 1915

In 1913, through his work with X-rays, he determined the actual nuclear charge (atomic number) of the elements.

He then arranged the elements in order of increasing atomic number (nuclear charge).



So, Henry Moseley lived between 1887 to 1915, that means he lived only for 28 years. In 1913, through his work with the X-rays, he determined the actual nuclear charge of the elements. He then arranged the elements in order of increasing atomic number, that is, nuclear charge.

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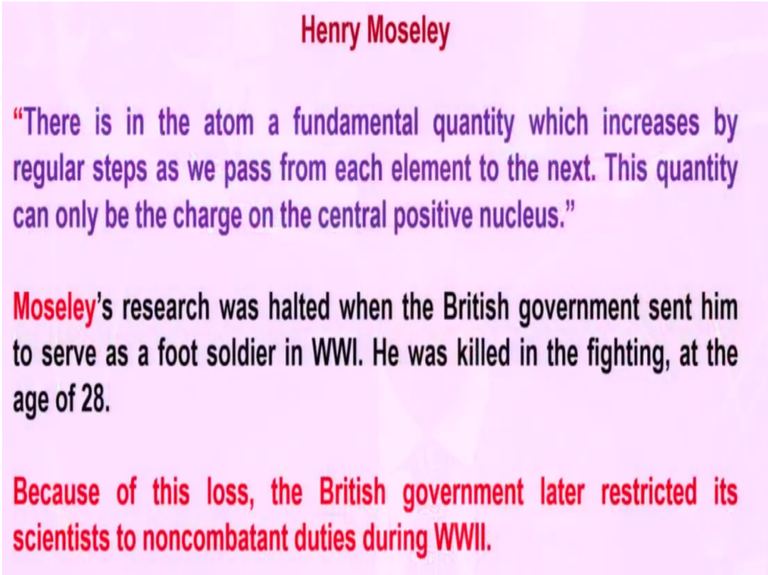

When we talk about Henry Moseley, he mentioned that there is in the atom a fundamental quantity which increases by regular steps as we pass from each element to the next. This quantity can only be the charge on the central positive nucleus. So, Moseley's research was halted when the British government sent him to serve as a foot soldier in World War One. So, he was killed in the fighting, at the age of 28. So, because of this loss, the British government later restricted its scientists to non-combatant ~~duties~~ duties, during World Wars.

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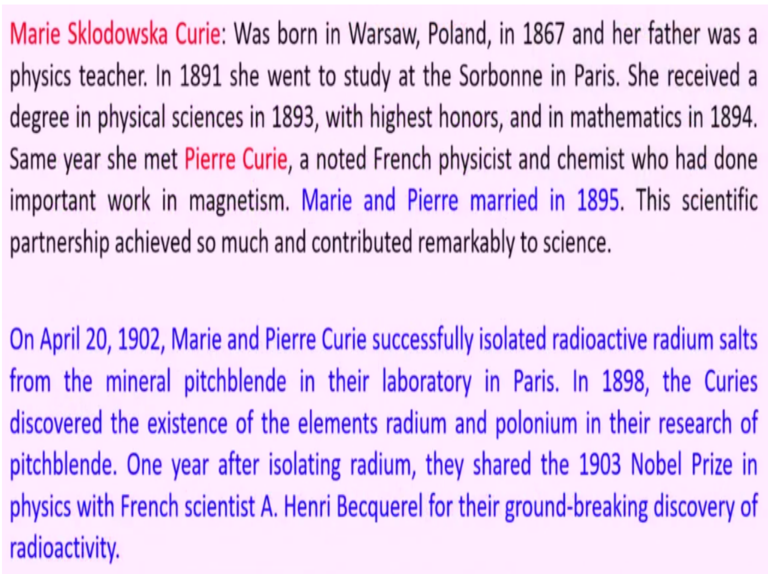

Now, let us look into an important chemist and a physicist who has contributed significantly to the understanding of radioactivity, Marie Curie. So Marie Curie was born in Warsaw, Poland in 1867 and her father was a physics teacher. So, in 1891 she went to study at the Sorbonne in Paris. She received a degree in physical sciences in 1893 with highest honours, and in mathematics in 1894.

Same year, she met Pierre Curie a~~nd~~ noted French physicist and chemist, who had done important work in magnetism. So, Marie and Pierre married in 1895. This scientific partnership achieved so much and contributed remarkably to science. On April 20,~~-~~1902, Marie and Pierre Curie successfully isolated radioactive radium salts from the mineral pitchblende in their laboratory in Paris.

In 1898, the Curies discovered the existence of the elements radium and polonium in the research of pitchblende. One year after isolating radium, they shared the 1903 Nobel Prize in Physics with French scientist A. Henri Becquerel, for their ground-breaking discovery of radioactivity. She is the first woman recipient of Nobel Prize.

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Pierre Curie was appointed to the chair of physics at the Sorbonne in 1904, and Marie continued her efforts to isolate pure, non-chloride radium. On April 19, 1906, Pierre Curie was killed in an accident in the Paris streets.

Although devastated, Marie Curie vowed to continue her work and in May 1906 was appointed to her husband's seat at the Sorbonne, thus becoming the university's first female professor.

In 1910, with Debierne, she finally succeeded in isolating pure, metallic radium.

For this achievement, she was the sole recipient of the 1911 Nobel Prize in chemistry, making her the first person to win a second Nobel Prize.

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Curie's daughter, Irene Curie, was also a physical chemist and, with her husband, Frederic Joliot, was awarded the 1935 Nobel Prize in chemistry for the discovery of artificial radioactivity. Marie Curie died in 1934 from leukemia caused by four decades of exposure to radioactive substances. In 1962, another Nobel prize was received by Marie's second daughter's husband who was the director of UNICEF

So, this is Curie, at the young age, and this is with Pierre Curie, on their way to work. So, Curie's daughter Irene Curie was also a physical chemist, and with her husband Frederick Joliot, was awarded Nobel Prize in Chemistry in 1935 for the discovery of artificial radioactivity. So, Marie Curie died in 1934 from leukemia blood cancer caused by four decades of her exposure to radioactive substances.

In 1962, another Nobel Prize was received by Marie's second daughter's husband who was the director of UNICEF. That means this Curie family has a credit of 5 Nobel Prizes, something remarkable and unbelievable achievement.

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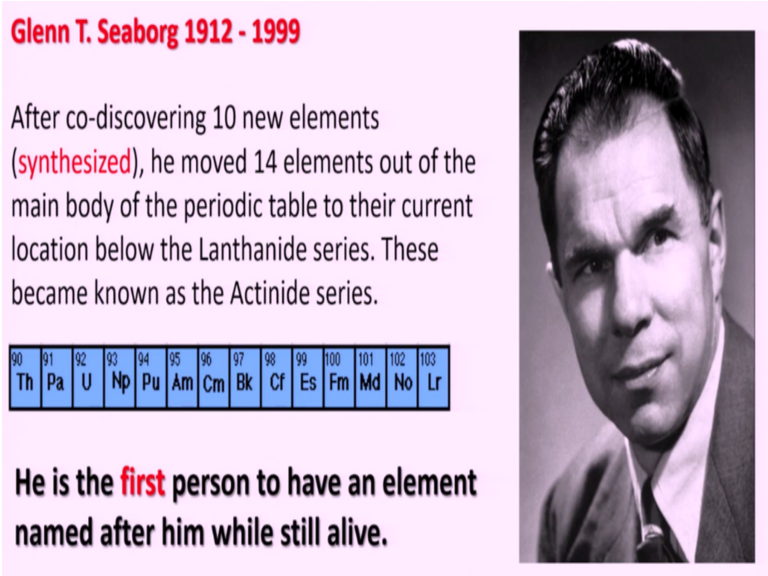

It is appropriate to remember Glenn T. Seaborg when it comes to post uranium elements or manmade elements. After co-discovering 10 new elements, synthesized in the laboratory or manmade, he moved 14 elements out of the main body of the periodic table to their current location below the Lanthanide series. These became known as the Actinide series, of course that has shown here from 90, thorium to lawrencium, 103. He is the first person to have an element named after him while still alive, Glenn T. Seaborg.

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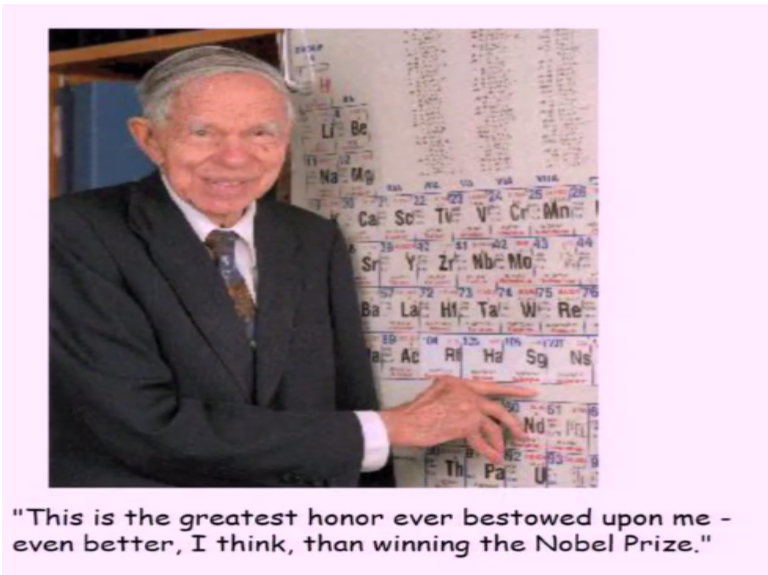

When that element was named after him, what he opine~~beye~~d, I have shown here, I read, I quote "this is the greatest honour ever bestowed upon me, even better, I think than winning the Nobel Prize," I unquote.

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On 23 March 2016, in a conference call a group of researchers decided the names of three of the latest elements in the periodic table. First, tennessine was proposed for 117, then moscovium for 115. Only the heaviest element yet discovered, element 118, remained nameless. 'Yuri,' a voice asked, 'can you leave the call?'

The remaining collaborators then made a unanimous decision. Yuri Oganessian is only the second living person, after US chemist Glenn Seaborg, to have an element named in their honor: Oganesson.

So, on 23rd March 2016, in a conference call, ~~led~~ a group of researchers decided the names of three of the latest elements in the periodic table. First, tennessine was proposed for atomic number 117, then moscovium for atomic number 115. Only the heaviest element ~~yet~~ just discovered was the element 118, it remained nameless. And then in the conference, one scientist Yuri Oganessian was there, somebody said: Oganessian, please leave the conference.

So, the remaining collaborators then made a unanimous decision to name the atomic number 118 element after Yuri Oganessian. So, that means Yuri Oganessian become the only second living person after US chemist Glenn Seaborg to have an element named in their honour Oganessian. That means the modern periodic table completed with the naming of the last element 118, after Oganessian.

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The reason for their choice was simple: Oganessian hadn't just led the international team to their discoveries, he had pioneered the very techniques they had used. In the 1970s, he had invented cold fusion – not the hypothesized low energy nuclear reaction, but a technique to produce superheavy elements – crucial to the discoveries of elements 104–113.

Now, his expertise in a new technique, branded hot fusion, had stretched the boundaries of knowledge to the end of the seventh row of the periodic table.

As Sherry Yennello, director of Texas A&M's Cyclotron Institute says, 'He's been a luminary in the field since forever – he's the grandfather of superheavy elements.'

And the reason is very simple and very appropriate for naming atomic number 118 as Oganesson because Oganessian had not just led the international team to their discoveries, he had pioneered the very techniques they used. In 1970s, he had invented cold fusion, not the hypothesized low energy nuclear reaction, but a technique to produce superheavy elements crucial to the discoveries of elements 104 to 113.

Now, his expertise in a new technique, branded hot fusion, had stretched the boundaries of knowledge to the end of the seventh row of periodic table. So as Sherry Yennello, director of Texas A and M's Cyclotron Institute says, I quote, "he has been a luminary in the field since forever, he is the grandfather of superheavy elements", I unquote.

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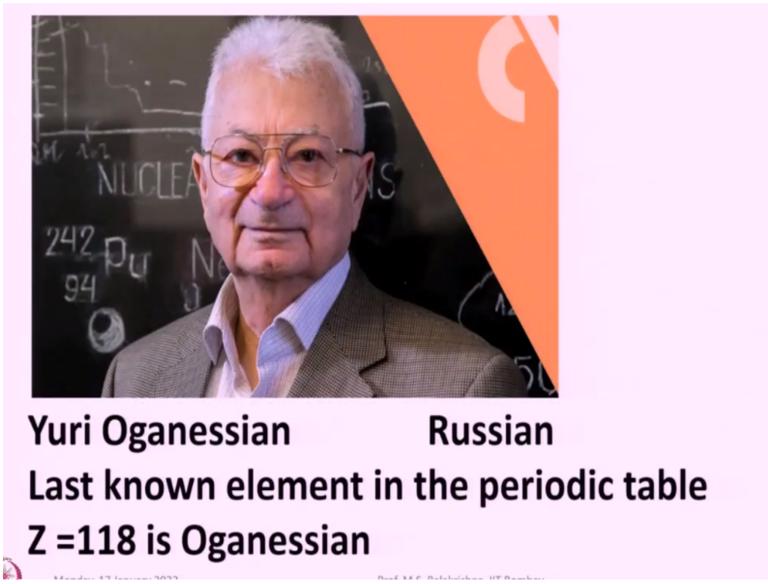

So, this is scientist Yuri Oganessian. The last known element in the periodic table being called as Oganessian.

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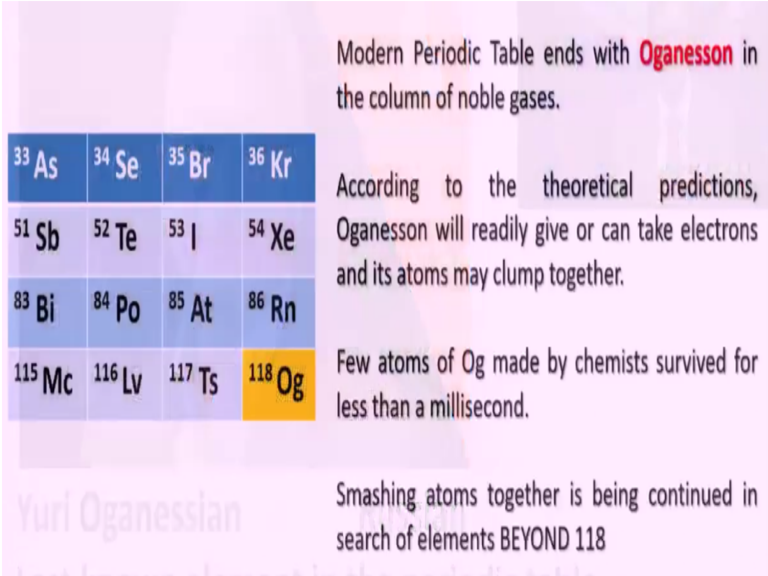

So, let us look into the modern periodic table. So modern periodic table ends with Oganesson in the column of noble gases here. After Radon, Oganesson is there. According to the theoretical predictions Oganesson will readily give or can take electrons and its atoms may clump together. Few atoms of Oganesson made by chemists survived for less than a millisecond.

That means you know how difficult, it is to work with, to establish their properties. Smashing atoms together is being continued in search of elements beyond 118. So let me stop at this juncture and continue more interesting stories about the periodic table in my third lecture. Until then, have an excellent time. Thank you.