Chemistry of Transactinides - II

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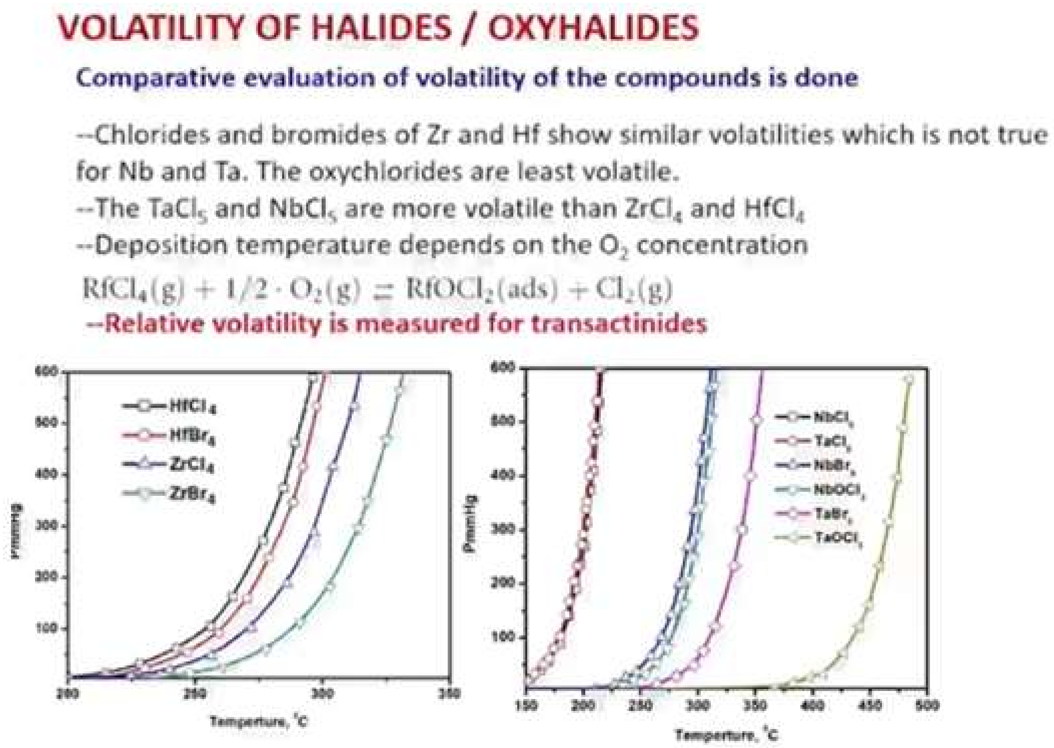
Week – 12
Lecture – 60

So, we were discussing about the transactinides and also today we will be covering the chemistry of some of the transactinides, the only transactinide elements like element number 104, 105 and 106. So, in the chemistry of transactinides, mostly there are two types of chemistry. One is the gas phase chemistry and the other is the solution phase chemistry. The gas phase chemistry is relatively easier because of the very fast transport in case of the gaseous molecules. But in the solution phase chemistry, there will be some sort of separation is required, which I have discussed in the previous lecture, how the atom-at-a-time-chemistry is done. So, the chemistry in the solution phase mostly involves partitioning type of experiments, i.e., ion exchange, chromatography or solvent extraction. So, we will come details of those chemical aspects in the aqueous phase and in the gas phase. While studying the gas phase chemistry, mostly the volatility of the halides or the oxyhalides is studied. Now, for these transactinide elements, they are part of the fourth transition series and the chemistry of these transactinides in the gas phase is always compared with the other elements in the second or third transition series. So, for example, if we are studying the gas phase chemistry of Rutherfordium, which is element 104, we need to study the volatility of Rutherfordium chloro compounds or the bromo compounds, that is $RfCl_4$, which is a volatile compound.



VOLATILITY OF HALIDES / OXYHALIDES

Comparative evaluation of volatility of the compounds is done

--Chlorides and bromides of Zr and Hf show similar volatilities which is not true for Nb and Ta. The oxychlorides are least volatile.

--The $TaCl_5$ and $NbCl_5$ are more volatile than $ZrCl_4$ and $HfCl_4$

--Deposition temperature depends on the O_2 concentration

$$RfCl_4(g) + 1/2 \cdot O_2(g) \rightleftharpoons RfOCl_2(ads) + Cl_2(g)$$

--Relative volatility is measured for transactinides

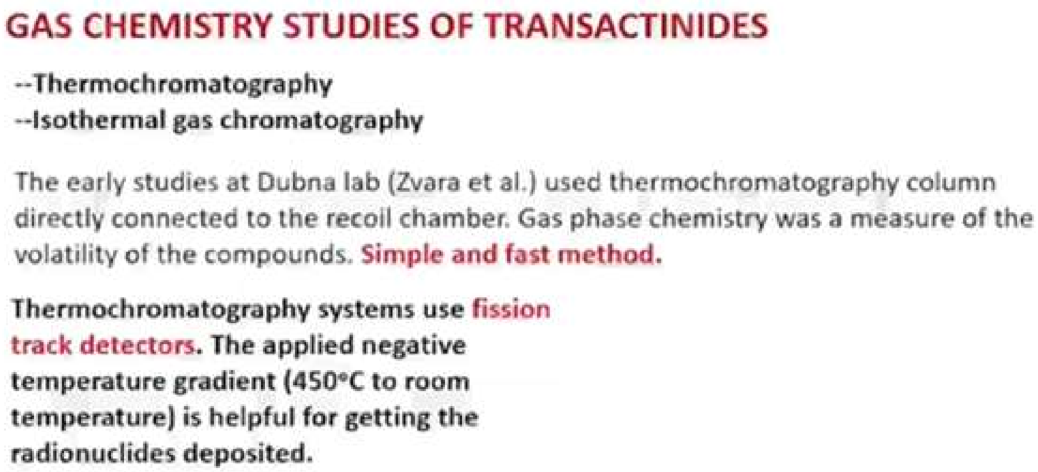
And we compare that with the transition elements like zirconium chloride or hafnium chlorides, i.e., $HfCl_4$ or $ZrCl_4$. Similar comparison also can be done with the bromide complexes like the $ZrBr_4$ and $HfBr_4$ compounds. And the same way, we can also compare the volatility of element 105 chlorides or bromides or oxychlorides, that is the Dubinium compounds with that of the Tantalum as well as the Niobium compounds. So, in this slide, we compare the volatility of these chloro, bromo or the oxychloro compounds. The left figure, it is the zirconium chloride and zirconium bromide and their volatility is compared with that of the hafnium chloro complex as well as the hafnium bromo complex, that is $HfCl_4$ and $HfBr_4$ complexes.

As you can see, the hafnium chloro and the bromo complexes are relatively more volatile as compared to that of the zirconium bromo complexes, as shown here. The hafnium chloro and hafnium bromo complexes are following the same pattern and their volatility is higher than that of the zirconium chloro and the bromo compounds. Now coming to the tantalum and niobium compounds, you can see that the chloro compounds of tantalum and niobium are more or less same as shown here. On the other hand, the bromo compounds have much lower volatility, shown in the profiles given here. This is for the tantalum bromide and also the niobium bromide compounds.

Now the oxychlorides, again, you have the tantalum oxychloride is having much lower volatility than that of the niobium oxychloride, which is having more or less similar volatility that of the niobium bromide. So in a similar manner, experiments can be done for the Rutherfordium chloro complexes and also to form their oxychloro complexes as given by this equation by reacting with oxygen and this can be compared with that of the zirconium hydro gas hafnium complexes.

$RfCl_{4(g)} + \frac{1}{2} O_{2(g)} \rightarrow RfOCl_{2(g)} + Cl_{2(g)}$

Now how these gas chemistry studies are carried out for the transactinides? The experimental method is rather simple. Two types of experimentation is done. One is the thermochromatography and other one is the isothermal gas chromatography.



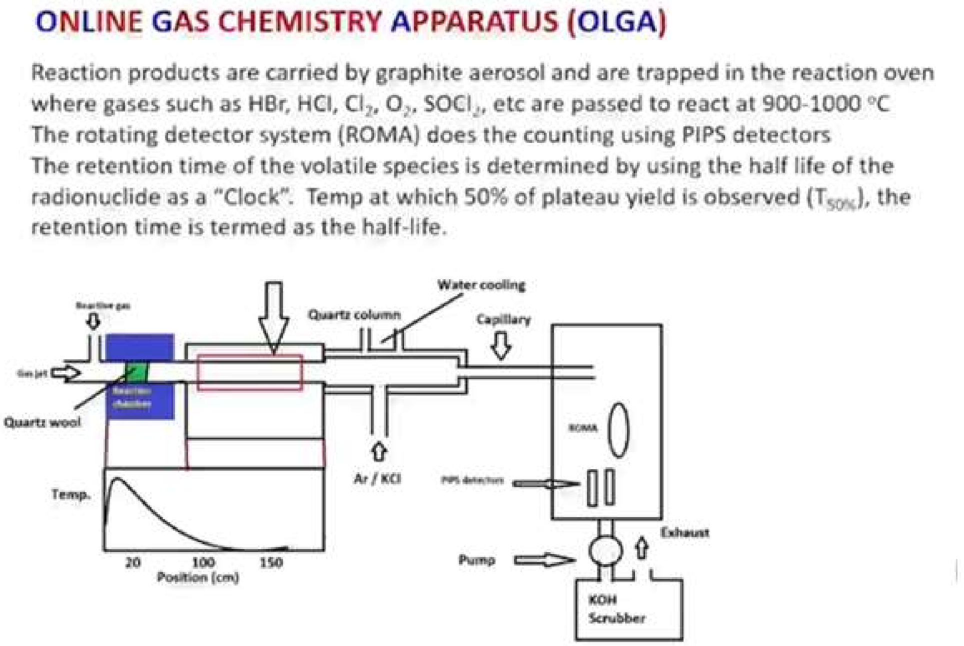
GAS CHEMISTRY STUDIES OF TRANSACTINIDES

--Thermochromatography
--Isothermal gas chromatography

The early studies at Dubna lab (Zvara et al.) used thermochromatography column directly connected to the recoil chamber. Gas phase chemistry was a measure of the volatility of the compounds. **Simple and fast method.**

Thermochromatography systems use fission track detectors. The applied negative temperature gradient (450°C to room temperature) is helpful for getting the radionuclides deposited.

The early studies, the Dubna lab in Russia, they used the thermochromatography column, which is directly connected to the recoil chamfer. So the gas phase chemistry was nothing but a measure of the volatility of the compound. This method was very simple and also very fast method. So in this case, the detection was done by fission track detectors. So basically, the thermochromatography as a function of the length of this column, which is there, basically you have a column and when this volatile compounds are passed from one end, so the temperature along this column is changed. So it goes from starting from 450 degrees to room temperature in this way going down and then depending on the volatility of the compound, they will be deposited and in this inside surface of this tube, the fission track detectors are implanted and by taking out the fission track detectors, you can monitor where exactly the compounds are deposited. Also, there are some disadvantages, even though this method is so simple. The real-time detection of the nuclear decay of the trans-actinides as well as their half-life determination and it was not possible.



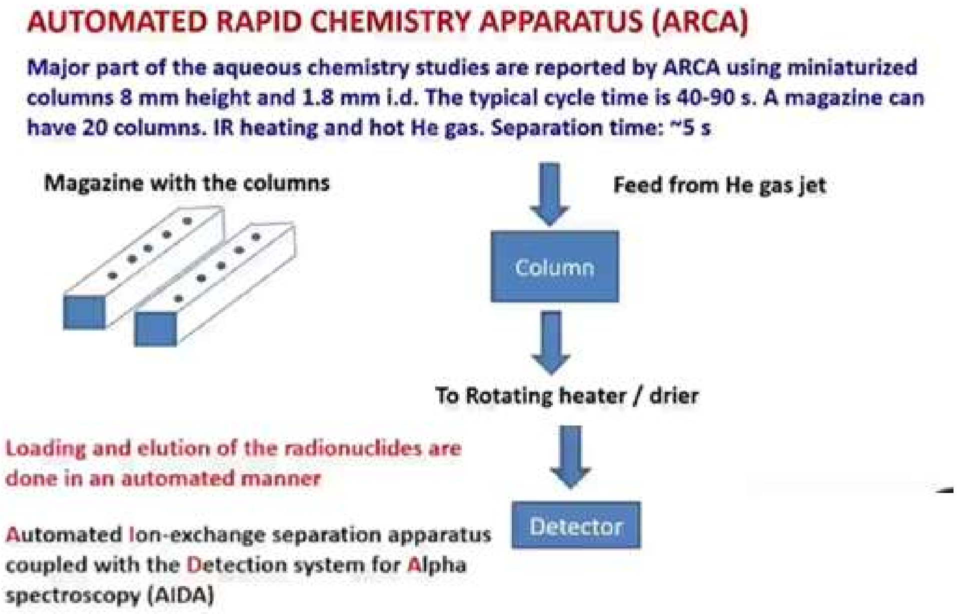
ONLINE GAS CHEMISTRY APPARATUS (OLGA)

Reaction products are carried by graphite aerosol and are trapped in the reaction oven where gases such as HBr, HCl, Cl_2, O_2, $SOCl_2$, etc are passed to react at 900-1000 °C

The rotating detector system (ROMA) does the counting using PIPS detectors

The retention time of the volatile species is determined by using the half life of the radionuclide as a "Clock". Temp at which 50% of plateau yield is observed ($T_{50\%}$), the retention time is termed as the half-life.

So subsequently this experimentation involved something called the isothermal gas chromatography, which is used by this online gas chromatography apparatus or OLGA. In this case, the reaction products are carried by graphite erosion and are trapped in the reaction oven where the gases such as hydrogen bromide, hydrogen chloride, chlorine, oxygen or $SOCl_2$ etc.are passed and are allowed to react with the transectinite atoms which are coming from the reaction chamber where the heavy ion reaction is taking place and the reaction is done at around 900 to 1000 degrees Celsius. And after that, these transactinide compounds are coming to be collected at this detector system which is called the ROMA, which is nothing but a rotating type of detector system and which is also going to be counted by alpha spectrometry by a set of PIPs detectors. Now in this case, the ROMA actually does the counting using the PIPs detector and the retention time of the volatile compounds, in this case the chloro, bromo or oxychloro complexes of the transactinide is determined by using the half-life of the radionuclide as a clock and the temperature at which the 50% plateau yield is observed, that is the T_{50}, the retention time is termed as the half-life. So that is how the half-life can be determined of these gaseous products of the trans-actinides. Now coming to the aqueous chemistry experiments, there are several sophisticated instruments (which) are used for this.



AUTOMATED RAPID CHEMISTRY APPARATUS (ARCA)

Major part of the aqueous chemistry studies are reported by ARCA using miniaturized columns 8 mm height and 1.8 mm i.d. The typical cycle time is 40-90 s. A magazine can have 20 columns. IR heating and hot He gas. Separation time: ~5 s

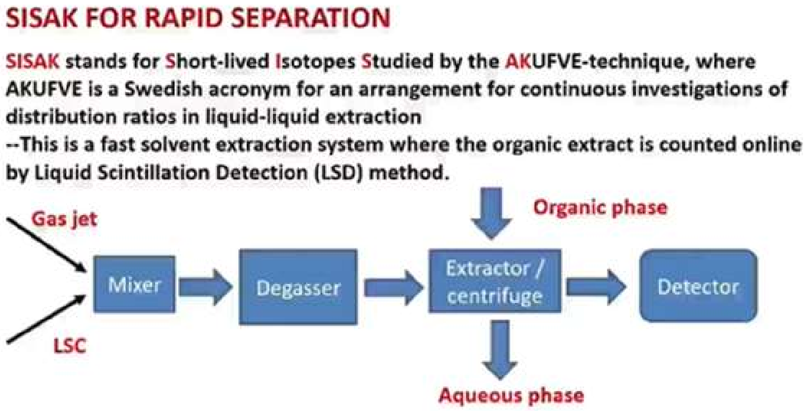
Loading and elution of the radionuclides are done in an automated manner

Automated Ion-exchange separation apparatus coupled with the Detection system for Alpha spectroscopy (AIDA)

This instrument has been designed in a special way such that these transectinite compounds can be separated and also can be detected using a special type detecting system. The first of such instrument is called the Automated Rapid Chemistry Apparatus or ARCA. Major part of the aqueous chemistry studies which are reported in the literature, they use ARCA which is having basically several miniaturized columns. The columns have 8 mm height and 1.8 mm internal diameter and the typical cycle time is around 40 to 90 seconds and there will be around 20 such columns in a ‘magazine’.

This ARCA system I can show in a little more clear view. As a schematic, I can show here where I have the front view as well as the side view as I was showing. This is the magazine actually. This one is the magazine where you have these columns embedded into the magazine. The column has around 8 mm height and a very very small column which are around 1.8 mm as the internal diameter. And this is the front view of the magazine here and this helium, gas jet, potassium, chloride gas jet system is coming here and it is forming a solution and the solution is passing through this. It comes to alternatively to these two magazines which are having the columns. It is passing through that and separately the eluent will be coming and the eluent will be passing through the column. That is how this effluent will be coming and will be collected into this plan check which will be dried and counted by either alpha or gamma spectrometry.

Alpha spectrometry for the transactinide and gamma spectrometry for the homologs which are like zirconium or hafnium isotopes which are short-lived and those are used sometimes to monitor the chemistry in an online method the way the transactinide experiment is done. In such case the zirconium, hafnium online data can be compared with the Rutherfordium online data. In a similar manner offline experiments are also done taking relatively more stable compounds of zirconium and hafnium or niobium and tantalum or in case of Seaborgium experiments, it is the molybdenum and tungsten isotopes are used. And in this case, mostly you have these different micro columns in the ARCA system. Subsequently, this has been also upgraded by the Japanese researchers to be called as automated ion exchange separation apparatus coupled with the detection system for alpha spectroscopy which is called as IDA.



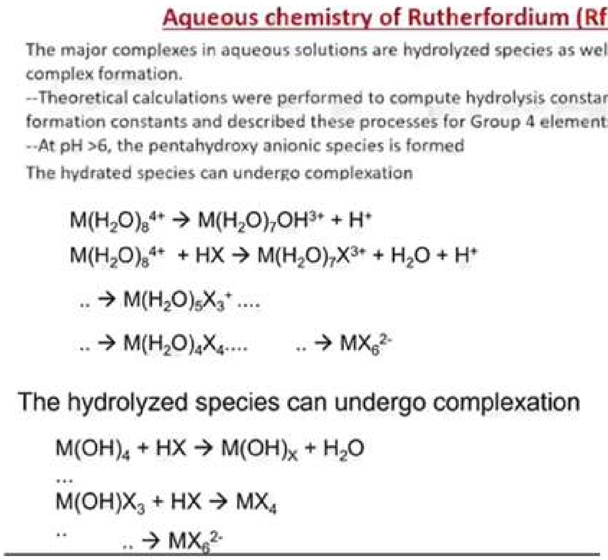
SISAK FOR RAPID SEPARATION

SISAK stands for Short-lived Isotopes Studied by the AKUFVE-technique, where AKUFVE is a Swedish acronym for an arrangement for continuous investigations of distribution ratios in liquid-liquid extraction

--This is a fast solvent extraction system where the organic extract is counted online by Liquid Scintillation Detection (LSD) method.

Now another type of instrument which is used for this fast separation for the transactinides is called the SISAK or this is the short lived isotope studies by the AKUFVE technique. AKUFVE is a very fast extraction, in this case extraction is by solvent extraction. So, AKUFVEis a solvent extraction system where automatically after equilibration of the organic and the aqueous phases, a part of this mixture will be pipetted out and it will be centrifuged and separated all these things in a very very short time period such that these experiments can be carried out in several minutes or so in case of the AKUFVEsystem. And some cases it can be done even faster to go to the second level and there is used for the transactinide separation chemistry studies. And this SISAK has been developed by the Swedish research groups and they have used, this is a system is given where you have actually several extraction as well as centrifuge methods are there.

This setup is there and you have the aqueous phase going into this and the gas phase also is going inside this and they will be mixed here and then the degassing can be done and it will go into the extraction as well as the centrifuge phase here where the organic phase will be inserted into this system. So, fast extraction and centrifuge is done then the aqueous phase will be taken out of the system and the organic phase will be going this way and it will be countered by the liquid scintillation counter. So, this is very very fast system and several experiments have been carried out by this SISAK setup which I will be discussing for some of the transactinides. Now coming to the individual transactinides, first let us go to the Rutherfordium or the element 104. We discuss first the aqueous chemistry of Rutherfordium.



Aqueous chemistry of Rutherfordium (Rf)

The major complexes in aqueous solutions are hydrolyzed species as well as the halide complex formation.

--Theoretical calculations were performed to compute hydrolysis constants and complex formation constants and described these processes for Group 4 elements (M=Zr, Hf, Rf).

--At pH >6, the pentahydroxy anionic species is formed

The hydrated species can undergo complexation

$M(H_2O)_8^{4+} \rightarrow M(H_2O)_7OH^{3+} + H^+$

$M(H_2O)_8^{4+} + HX \rightarrow M(H_2O)_7X^{3+} + H_2O + H^+$

$.. \rightarrow M(H_2O)_5X_3^+ ....$

$.. \rightarrow M(H_2O)_4X_4 .... \quad .. \rightarrow MX_6^{2-}$

The hydrolyzed species can undergo complexation

$M(OH)_4 + HX \rightarrow M(OH)_X + H_2O$

...

$M(OH)X_3 + HX \rightarrow MX_4$

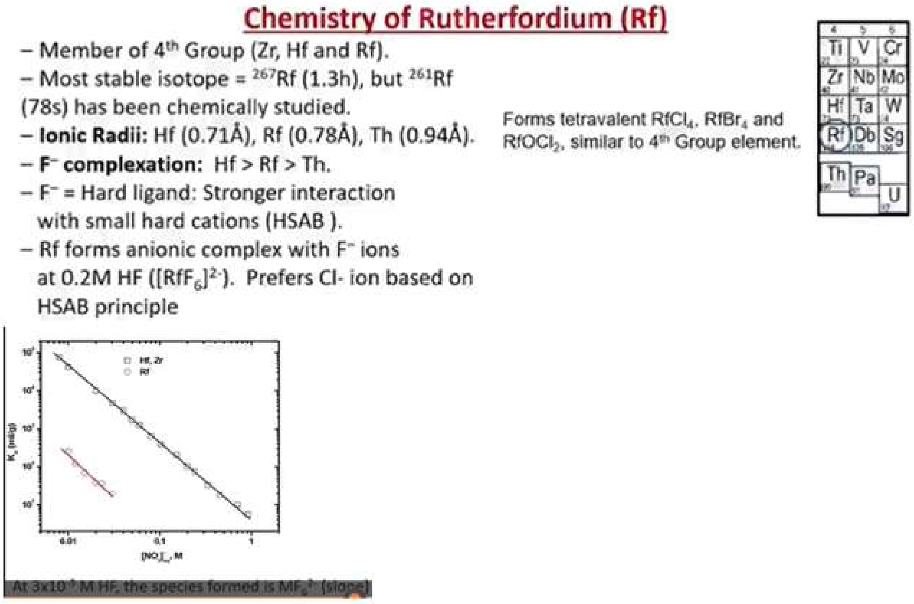
$.. \quad .. \rightarrow MX_6^{2-}$

The major complex says as we know what the actinides and the transactinides are the hydrolyzed species in case of the aqueous phases. So therefore, the acidity of the aqueous phase needs to be controlled. It is normal pH conditions then we are having the hydrolyzed species. So for the group 4 elements like Rutherfordium and its homologs like zirconium and hafnium, we have that this at pH greater than 6 we get the pentahydroxyanionic species which is like this $M(H_2O)(OH)_5^-$ this type of species and we can have X number of H_2O. So, these type of species will be formed for the tetravalent metal ions like Rutherfordium as well as zirconium and hafnium.

The hydrated species can undergo also complexation. Here I have shown how this hydrated species can form a complex with complexing agent like HX where X^- is the anionic species which is forming a complex. So, the species if it is not having hydroxide species then it can form like $MX(H_2O)_7^{3+}$ that means the tetravalent ion is not having any hydroxo complex. In that case it will form complexes like this and it will continue to form the complexes till it has completely anionic complexes like MX_6^{2-}. The example of this type of complexation is MX_6^{2-}. So that is our fluoride complexes of zirconium, hafnium or Rutherfordium. This forms species like MF_6^{2-} and the hydrolyzed species also can form complexes like I have mentioned here. You can have a precipitated form of this tetrahydroxy complexes ($M(OH)_4$) of the tetravalent metal ions like zirconium, hafnium or Rutherfordium. And this precipitate can form complexes with HX giving $M(OH)_x$ and H_2O and subsequent complexation can take place to give MX_4 type of species. And MX_4 also can complex with another HX to give MX_5^- and subsequently with another HX to give

MX_6^{2-} giving species like this as mentioned.

Now coming to the aqueous chemistry of Rutherfordium, we know that Rutherfordium is a member of the fourth group as shown here. So it has an oxidation state of plus 4 and it has ionic size of 0.78Å. Hafnium is having ionic size of 0.71Å and thorium 0.94Å.



Chemistry of Rutherfordium (Rf)

- Member of 4th Group (Zr, Hf and Rf).
- Most stable isotope = ^{267}Rf (1.3h), but ^{261}Rf (78s) has been chemically studied.
- **Ionic Radii:** Hf (0.71Å), Rf (0.78Å), Th (0.94Å).
- **F^- complexation:** Hf > Rf > Th.
- F^- = Hard ligand: Stronger interaction with small hard cations (HSAB).
- Rf forms anionic complex with F^- ions at 0.2M HF ($[RfF_6]^{2-}$). Prefers Cl- ion based on HSAB principle

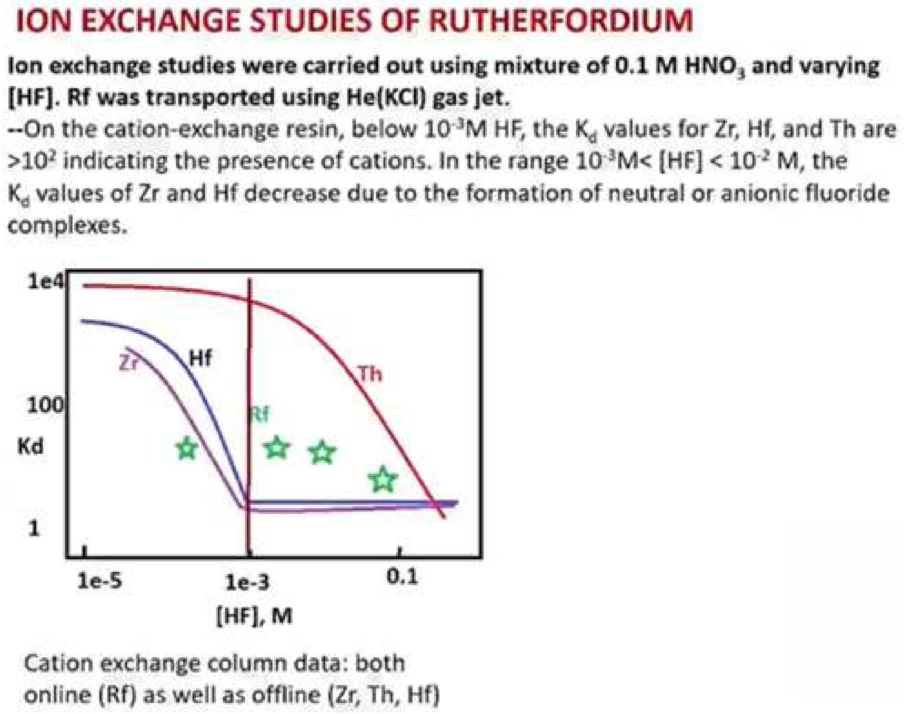
Forms tetravalent $RfCl_4$, $RfBr_4$ and $RfOCl_2$, similar to 4th Group element.

At $3x10^{-3}$ M HF, the species formed is MF_6^{2-} (slope)

Why I mentioned thorium here? Because thorium is actinide species as mentioned here and this is called as the pseudo-homolog of Rutherfordium. So, the transition elements in the group 4 like titanium and zirconium they are considered as the homolog of Rutherfordium and thorium is considered as the pseudo-homolog of Rutherfordium. Now based on this ionic size, this is for the hexa coordination, the fluoride complexation will follow the ionic potential. So that is hafnium is greater than that of Rutherfordium is greater than that of thorium.

Fluoride is a hard ligand, it can form a stronger interaction with the hard cations like hafnium, zirconium and to some extent Rutherfordium. So Rutherfordium forms anionic complexes like RfF_6^{2-} and it also prefers to form complexes with the fluoride ion based on the hard soft acid base principle because it is relatively softer as compared to hafnium. So I have shown a figure here where the experiments have been carried out by the ARCA system and the system contains a small quantity of hydrogen fluoride that is $3x10^{-3}$ M hydrogen fluoride and also varying concentration of nitrate that is a nitric acid concentration is varying and the K_d values are determined and you can see here that the species which is formed is RfF_6^{2-} or for zirconium and hafnium it is MF_6^{2-} where M is either zirconium or hafnium and with increasing nitrate concentration you find that this K_d

value is decreasing with a negative slope of minus 2 suggesting that the attracted species is indeed MF_6^{2-} . This type of species are formed and with increasing nitrate ion concentration this K_d value is becoming less and less and same type of species was also seen in the case of Rutherfordium your minus 2 slope here so that suggests that the expected species is MF_6^{2-} in this case and the chemistry of Rutherfordium as shown here is similar to that of zirconium and hafnium.



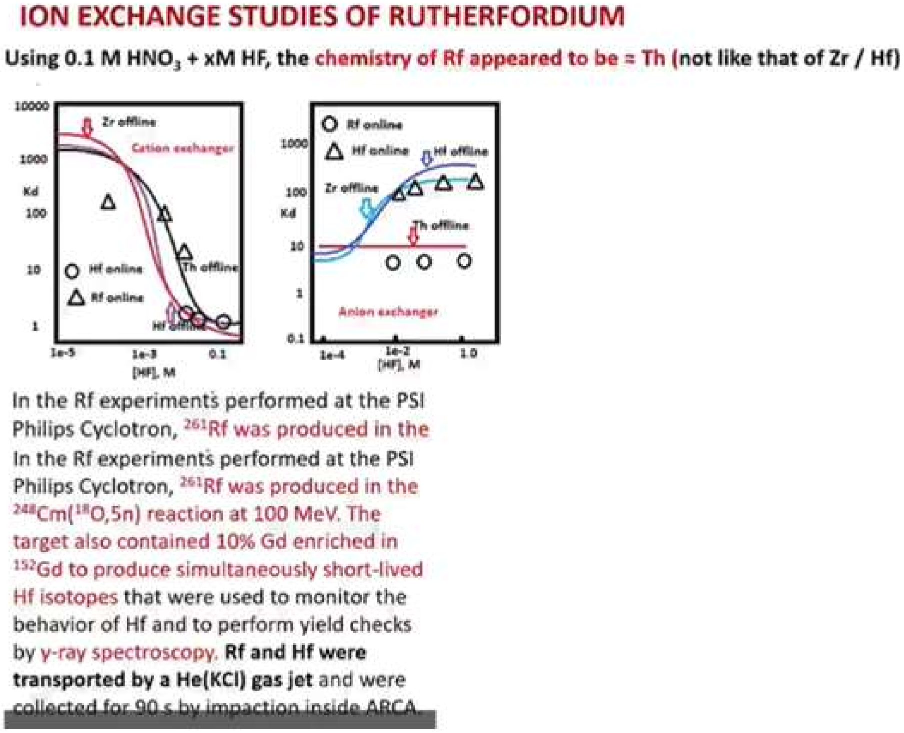
ION EXCHANGE STUDIES OF RUTHERFORDIUM

Ion exchange studies were carried out using mixture of 0.1 M HNO_3 and varying [HF]. Rf was transported using He(KCl) gas jet.

--On the cation-exchange resin, below 10^{-3}M HF, the K_d values for Zr, Hf, and Th are $>10^2$ indicating the presence of cations. In the range $10^{-3}M < [HF] < 10^{-2}$ M, the K_d values of Zr and Hf decrease due to the formation of neutral or anionic fluoride complexes.

Cation exchange column data: both online (Rf) as well as offline (Zr, Th, Hf)

Also ion exchange studies have been carried out by Rutherfordium where the study has been carried out with varying concentration of nitric acid that is 0.1 M nitric acid has been taken in these experiments that is a mixture of nitric acid and hydrofluoric acid and the Rutherfordium was transported using the potassium chloride helium gas jet transport system and on the cation exchange regime you can see that at the hydrochloric acid concentration of around 10^{-3} M or lower you can find out this K_d values are becoming very very large so that means the anionic species are not formed and the cationic complexes they are absorbed onto the cation exchange regime but if you increase the HF concentration beyond 10^{-3} M you find that this K_d values are dropping and as shown here the comparison has been done between this uptake of zirconium hafnium thorium and Rutherfordium using this cation exchange column zirconium hafnium and thorium data are generated by offline method whereas the Rutherfordium data was generated by online method which is very obvious and you see here that the thorium offline data is actually entirely different than what has been seen for the zirconium and hafnium zirconium hafnium is falling a pattern here and Rutherfordium is in between. Rutherfordium is falling actually in between that means it is at some experiments it may be falling close to that of the zirconium and hafnium data and some other cases it is lying in between that of thorium as well as zirconium and hafnium. So to get some more clarification, the ion exchange studies were carried out again with offline and in this case some online experiments also were carried out using hafnium so Rutherfordium experiments are always carried out online but the hafnium data presented here the left hand side figure is both offline as well as online and you can see that this hafnium online data which is the solid circle and the hafnium offline data which is the purple line shown here there are more or less matching and you have the thorium offline data which is lying here which is matching in this case.



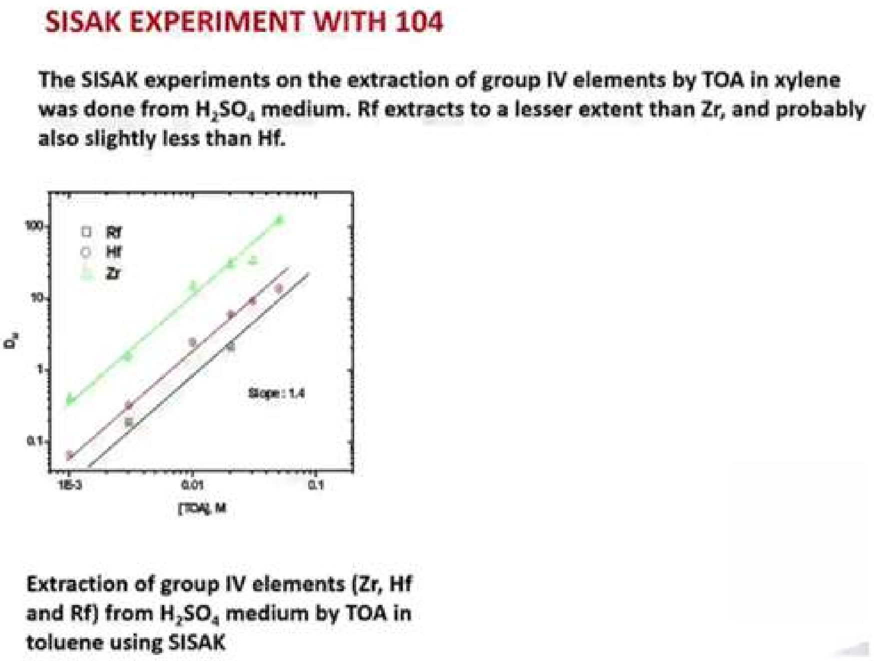
ION EXCHANGE STUDIES OF RUTHERFORDIUM

Using 0.1 M HNO_3 + xM HF, the chemistry of Rf appeared to be ≈ Th (not like that of Zr / Hf)

In the Rf experiments performed at the PSI Philips Cyclotron, ^{261}Rf was produced in the

In the Rf experiments performed at the PSI Philips Cyclotron, ^{261}Rf was produced in the $^{248}Cm(^{18}O,5n)$ reaction at 100 MeV. The target also contained 10% Gd enriched in ^{152}Gd to produce simultaneously short-lived Hf isotopes that were used to monitor the behavior of Hf and to perform yield checks by γ-ray spectroscopy. **Rf and Hf were transported by a He(KCl) gas jet** and were collected for 90 s by impaction inside ARCA.

Surprisingly with the Rutherfordium online data you see these triangles are the Rutherfordium online data so for the cation exchange column experiments the thorium data is matching with that of the Rutherfordium online data and this experiment was repeated using an anion exchange regime. So the experimental condition is same but you have a reverse pattern here in case of the cation exchange regime. Initially the K_d value was low that is that low concentration of HF where the fluoride complexation was not there. Those cases you have the cationic species and we are absorbed into the columns and in case of the anion exchange regime you find that lower concentration of HF because anionic complexes are not formed. So the uptake onto the anion exchange regime is not there you find the very low K_d values. But at higher concentration of HF you find that the anionic species are formed and then you find that the K_d values are going up. But what is interesting in this case is that through the hafnium offline as well as the hafnium online data they suggest some increase actually with increasing the HF concentration. And also which is matching with the zirconium offline data which is shown here. The thorium data actually is showing no change at all that means thorium is not forming a fluoride complex and surprisingly the Rutherfordium also gave the data which are matching with the thorium data points. So the cation exchange as well as the anion exchange experiments which have Rutherfordium, zirconium, hafnium and thorium, the conclusion was that Rutherfordium and thorium data points were matching with both the type of regime.



SISAK EXPERIMENT WITH 104

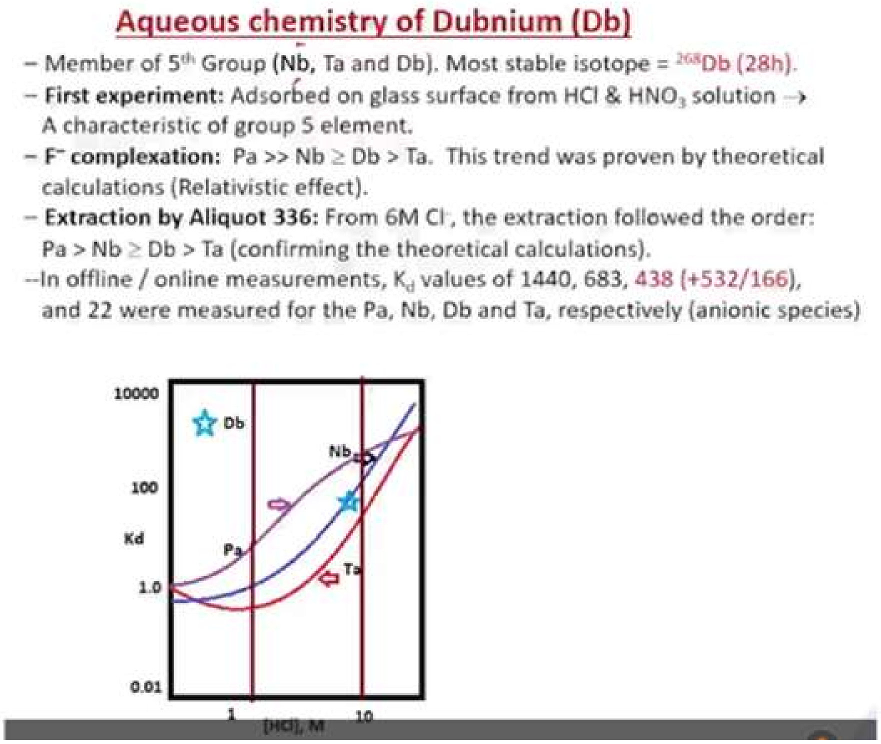
The SISAK experiments on the extraction of group IV elements by TOA in xylene was done from H_2SO_4 medium. Rf extracts to a lesser extent than Zr, and probably also slightly less than Hf.

Extraction of group IV elements (Zr, Hf and Rf) from H_2SO_4 medium by TOA in toluene using SISAK

Now coming to the SISAK experiments with element 104 that is Rutherfordium in this case the solvent extraction experiments were carried out with the group 4 elements using trioctyl amine (TOA) which is a tertiary amine in xylene and the experiment was done from the sulfuric acid medium and as shown here the data of zirconium, hafnium and Rutherfordium all in the tetravalent and the plus four oxidation states. The distribution ratio values increase as a function of the TOA that is the trioctyl amine concentration. And you find the straight line plots in these log-log plots and the slope value of these lines are around 1.4 and which is more or less consistent for all the three types of metal and suggesting that the mixed type of extracted species are formed. That is to say this extracted species is having either one or two amines so that is how you get a mixed species and the slope value is around 1.4. So this experiment also shows that the pattern of zirconium, hafnium and Rutherfordium if we see that the zirconium extraction is the highest and followed by the hafnium extraction and which is followed by the Rutherfordium extraction.

But you find that this Rutherfordium extraction is comparatively lower than that of hafnium extraction.

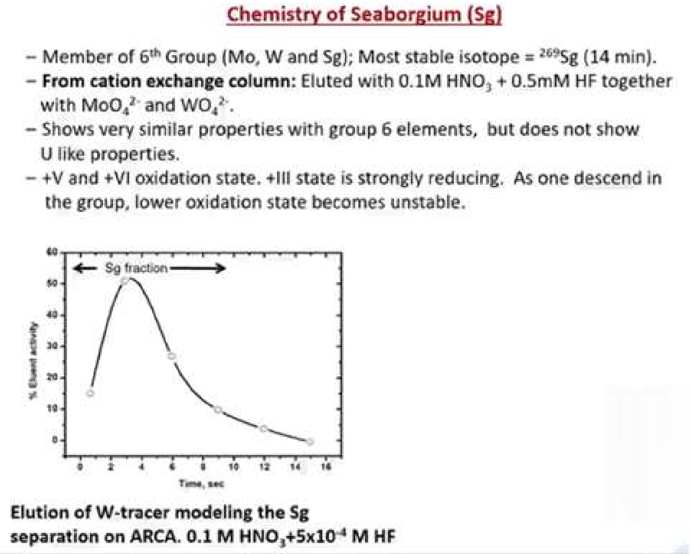
Now I come to the element number 105 which is the the dubnium and I mentioned here that aqueous chemistry of dubnium, dubnium again it is has the homolog vanadium niobium and tantalum. It has a pseudohomolog as the protactinium is a member of the fifth group as mentioned so we have niobium, tantalum and dubnium which are forming the same group. And the first experiment was carried out in this case was the adsorbs on the glass surface from the HCl and nitric acid solutions which is again a characteristic of the some of the group five elements. Lower is the complexation, the trend shown here by theoretical calculations taking into consideration their relativistic effects. That is protactinium should have highest complex formation with the fluoride ion followed by niobium followed by dubnium or niobium and dubnium. They may be having more or less same complex formation tendency and tantalum should be having the least complexation with fluoride ion so this was tested by extraction studies using Aliquat 336 from 6 M chloride solution this extraction followed the order (as given below).



Aqueous chemistry of Dubnium (Db)

- Member of 5th Group (Nb, Ta and Db). Most stable isotope = ^{268}Db (28h).
- **First experiment:** Adsorbed on glass surface from HCl & HNO_3 solution → A characteristic of group 5 element.
- **F^- complexation:** Pa >> Nb ≥ Db > Ta. This trend was proven by theoretical calculations (Relativistic effect).
- **Extraction by Aliquot 336:** From 6M Cl^-, the extraction followed the order: Pa > Nb ≥ Db > Ta (confirming the theoretical calculations).
- -In offline / online measurements, K_d values of 1440, 683, 438 (+532/166), and 22 were measured for the Pa, Nb, Db and Ta, respectively (anionic species)

Protactinium followed by niobium followed by dubnium followed by tantalum so this confirms the theoretical calculation and the K_d values in the offline as well as online measurements for a particular condition is given here. You can see that the K_d values around 1440 for protactinium which is very very high compared to that of niobium that is 683 and dubnium value is around 438 and which is again very very large compared to that of tantalum which is only 22. From the K_d value itself you can see that at this condition these K_d values are given. Now another example: I give the aqueous chemistry of dubnium so these studies are carried out using a mixture of hydrochloric acid and hydrofluoric acid using arca and the extraction chromatography studies are carried out using tri-octyl amine as the extractant. The extraction of niobium, tantalum, protactinium (which is a pseudo homolog) has been taken into consideration and dubnium into tri-isoptylamine from 12 molar HCl and 0.02 molar hydrofluoric acid and also from 10 molar HCl studies were carried out. And in this case, dubnium was found to be extracted together with niobium tantalum and protactinium that means all four elements were extracted together but after the first extraction step the niobium and protactinium fraction was eluted with 4 molar HCl and 0.02 molar HF. And the tantalum fraction was eluted with 6 molar HNO_3 and 0.0015 molar HF and the observation was that 88% of the dubnium was with the niobium protactinium fraction while only 12 percent was with the tantalum fraction. That suggests that dubnium is more or less following the similar chemistry of niobium and protactinium fraction now to find a further distinction 10M HCl containing 0.025 M HF, protactinium was eluted first and niobium was eluted with the 6 M HNO_3 containing 0.0015 M HF. But then in this case the distribution of dubnium was more or less equal with both these fractions that is around 25 % were seen with the protactinium fraction and 27 with the niobium fraction. So that whatever trend is seen from this experiment it doesn't match with what has been theoretically predicted. That means in this case tantalum is having higher extraction followed by niobium followed by protactinium and dubnium is somewhere also very close to that of protactinium.



Chemistry of Seaborgium (Sg)

- Member of 6th Group (Mo, W and Sg); Most stable isotope = ^{269}Sg (14 min).
- **From cation exchange column:** Eluted with 0.1M HNO_3 + 0.5mM HF together with MoO_4^{2-} and WO_4^{2-}.
- Shows very similar properties with group 6 elements, but does not show U like properties.
- +V and +VI oxidation state. +III state is strongly reducing. As one descend in the group, lower oxidation state becomes unstable.

Elution of W-tracer modeling the Sg separation on ARCA. 0.1 M HNO_3+$5x10^{-4}$ M HF

The last part in this series is the chemistry of seborgium seborgium is known to be member of the 6th group that is molybdenum and tungsten and it can also have a pseudo homolog of uranium so when the experiment is carried out for example the cation exchange column studies using ARCA has been done where the elution was done using 0.1 M nitric acid and 0.5 millimolar hydrochloric acid together with the MoO_4^{2-} and WO_4^{2-} these are eluted along with the seborgium suggesting that seborgium also may be species like SgO_4^{2-}. This type of species anionic species it may be forming but this seborgium does not follow the chemistry of uranium which was very clearly proven and another experiment was carried out in which 0.1 M nitric acid was used as the eluent and it suggested that seborgium is different from molybdenum and tungsten. Also based on the hydrolysis, it is considered entirely different as compared to molybdenum and tungsten molybdenum tungsten can form this neutral hydroxyl species like $MoO_2(OH)_2$ but it was reported that seborgium does not form this neutral type of species and always form a cationic species even at higher pH values. Now this is how I conclude the chemistry of this element 104 105 and 106.

To summarize, we see that these results from the recent studies they justify the positioning of the trans-actinides starting with element 104 into the seventh period of the periodic table and the chemical studies are performed with rutherfordium, dubnium and seaborgium both in aqueous as well as gas phase heavier trans-actinides gas phase chemistry also is reported. And all experimental results yield properties which place them in these elements into their respective groups in the periodic table. A closer look reveals that their chemical properties cannot be predicted in comparison with their lighter homologs. However, the modern relative molecular calculation show excellent agreement with the experimental data. Therefore, one can deduce that the relativistic effects strongly influence the chemical properties of the trans-actinides. Subsequent experiments with element 118 has been also carried out recently these elements 119, 120 and 121 have been identified but need confirmation. This will start period 8 in the periodic table and these studies are mostly carried out in the Lawrence Berkeley National Laboratory, USA, the Dubna lab in Russia, the GSI lab in Germany and also in Japan.

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