# Advance Analytical Course

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## Lecture No. # 24

Microwave wet digestion – three things have to be kept in mind, that when we are analysing the glass samples, particularly glass sample of the type SRM 621, which is a multi-element composite and which is embedded in the silicates, it needs to have a proper microwave digestion programming.

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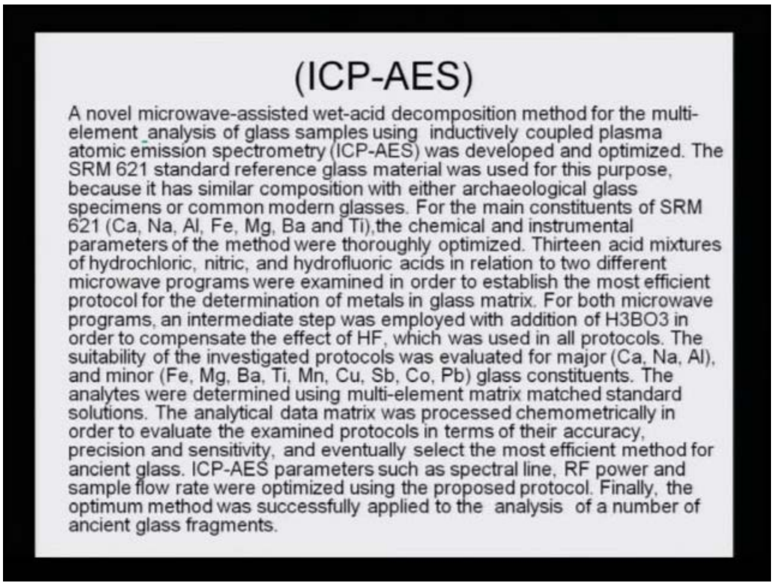

(ICP-AES)

A novel microwave-assisted wet-acid decomposition method for the multi-element analysis of glass samples using inductively coupled plasma atomic emission spectrometry (ICP-AES) was developed and optimized. The SRM 621 standard reference glass material was used for this purpose, because it has similar composition with either archaeological glass specimens or common modern glasses. For the main constituents of SRM 621 (Ca, Na, Al, Fe, Mg, Ba and Ti),the chemical and instrumental parameters of the method were thoroughly optimized. Thirteen acid mixtures of hydrochloric, nitric, and hydrofluoric acids in relation to two different microwave programs were examined in order to establish the most efficient protocol for the determination of metals in glass matrix. For both microwave programs, an intermediate step was employed with addition of $H_3BO_3$ in order to compensate the effect of HF, which was used in all protocols. The suitability of the investigated protocols was evaluated for major (Ca, Na, Al), and minor (Fe, Mg, Ba, Ti, Mn, Cu, Sb, Co, Pb) glass constituents. The analytes were determined using multi-element matrix matched standard solutions. The analytical data matrix was processed chemometrically in order to evaluate the examined protocols in terms of their accuracy, precision and sensitivity, and eventually select the most efficient method for ancient glass. ICP-AES parameters such as spectral line, RF power and sample flow rate were optimized using the proposed protocol. Finally, the optimum method was successfully applied to the analysis of a number of ancient glass fragments.

13 acid mixtures of hydrochloric acid, nitric acid and hydrofluoric acid mixtures have been utilized to be able to completely digest the samples for all the metal contents, such as calcium, sodium, aluminium as major components, and in minor components, iron, magnesium, barium, titanium, manganese, copper, antimony, cobalt and lead. The analytes were determined using multi-element matrix matched standard solution. Obviously, it is always a calibration method. So, the standard also must have all these components to be able to analyse the same metals in the sample. The analytical data matrix was processed chemometrically in order to evaluate the examined protocols in terms of their accuracy, precision and sensitivity, and eventually, select the most efficient

method for the ancient glass. So, there was some permutation and combination in the method that was developed. And, the best method that gave the best analytical data in terms of its chemometric manipulation was the one which was used for analysis of the ancient glass samples or the archaeological samples.

ICP-AES parameters, such as spectral line, RF power and sample flow rate were optimized using protocol, which were used in the process. So, these are the three things which were manipulated. The spectral lines – that means which line to choose. The other day, I was mentioning when I was talking about ICP and AAS, I said that in ICP, we can do multi-element analysis and while we are doing multi-element analysis, if the two metal have very close spectral lines, then we choose the second grade of the spectral lines for the second elements, so that there is no interferences caused by the spectral lines. And, there should not be any confusion, because the two metals may not be able to be discriminated properly. Finally, the optimal method was successfully applied to the analysis of a number of ancient glass fragments. To be able to know what the glass composition was at that time or what was their methodology to prepare these very different types of glass material, which are compared with the modern glass, one needs to understand the composition of these in terms of their metal content.

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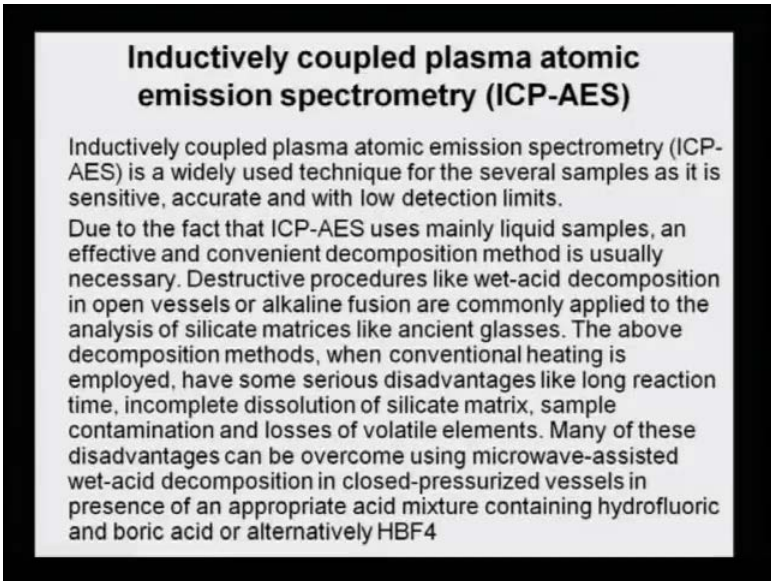

## Inductively coupled plasma atomic emission spectrometry (ICP-AES)

Inductively coupled plasma atomic emission spectrometry (ICP-AES) is a widely used technique for the several samples as it is sensitive, accurate and with low detection limits.

Due to the fact that ICP-AES uses mainly liquid samples, an effective and convenient decomposition method is usually necessary. Destructive procedures like wet-acid decomposition in open vessels or alkaline fusion are commonly applied to the analysis of silicate matrices like ancient glasses. The above decomposition methods, when conventional heating is employed, have some serious disadvantages like long reaction time, incomplete dissolution of silicate matrix, sample contamination and losses of volatile elements. Many of these disadvantages can be overcome using microwave-assisted wet-acid decomposition in closed-pressurized vessels in presence of an appropriate acid mixture containing hydrofluoric and boric acid or alternatively HBF4

Inductively coupled plasma atomic emission spectrometry – again and again, I am telling about these machines in so much of great details, because one analyser should be able to discriminate what to use and where to use. Inductively coupled plasma atomic emission spectrometry, that is, ICP-AES is a widely used technique for the several samples as it is sensitive, accurate and with low limits of detection. Due to the fact that ICP-AES uses mainly liquid samples, an effective and convenient decomposition method is usually necessary. So, now, we know that this is a method, which can be used for any and every sample although it is sensitive and accurate and goes up to lower limit of detection. Therefore, the only challenge that an analyser or an analyst has to face is to be able to prepare the liquid sample most effectively and most conveniently. If the decomposition or digestion step is very cumbersome or long drawn, then it is not a very good technique and cannot be adopted by every laboratory. Hence, the decomposition method should be very efficient. And, that is the most important step, because as I told you, silicate or glass samples are very tough to digest, and unless and until there is a complete wet digestion of these glass silicates, it is not possible to get all the metals extracted into the solution. And, unless and until all the metal come into the solution, the analysis can never be exhausted and complete.

Destructive processes like wet-acid decomposition in open vessels or alkaline fusion are commonly applied to the analysis of silicate matrices like ancient glasses. The above decomposition methods, when conventional heating is employed, have some very serious disadvantages like long reaction time, incomplete dissolution of silicate matrix, sample contamination and losses of volatile elements. Many of these disadvantages can be overcome using microwave-assisted wet-acid decomposition in closed-pressurized vessels in presence of an appropriate acid mixture containing hydrofluoric and boric acid or alternatively, HBF4, that is, the hydra fluoro boro acid. So, you see that what the disadvantages are if we try to digest these glass samples in open vessels. There are several and very serious disadvantages; that is, firstly, it is a very long process and it may or may not completely digest the silicate. And, as what I told you, if the silicate matrix does not get completely digested, the metals that are embedded inside, which are much smaller in quantities or even in sometimes trace quantities, cannot be extracted or digested into the solution. And, unless and until they come into the solution, it is not possible to analyse them by ICP-AES, and the sample in the open vessel may get contaminated by outside agencies. And, sometimes, the volatile elements also may be lost, because there is an open vessel and it is getting heated, and the volatile elements can go away from the matrix or from the dissolved solution. So, that is why it was important to design a method of microwave-assisted wet-acid decomposition, because it is carried out in pressurised teflon vessels, and therefore, because it is made up of teflon, it does not get affected by any of these acids like hydrochloric acid, nitric acid, boric acid or even hydrofluoric acid. And, sometimes, the combination of boric acid and hydrofluoric acid has also been taken into account for the complete dissolution of the silicate matrix.

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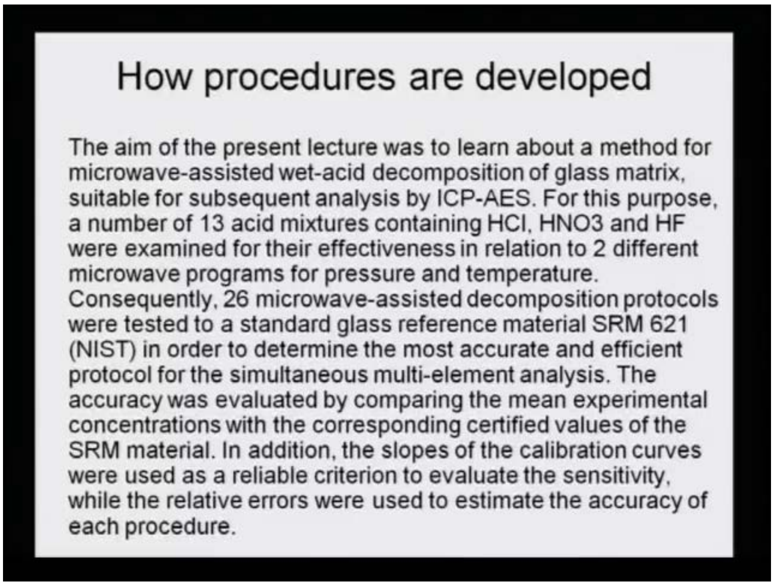

## How procedures are developed

The aim of the present lecture was to learn about a method for microwave-assisted wet-acid decomposition of glass matrix, suitable for subsequent analysis by ICP-AES. For this purpose, a number of 13 acid mixtures containing HCl, HNO3 and HF were examined for their effectiveness in relation to 2 different microwave programs for pressure and temperature. Consequently, 26 microwave-assisted decomposition protocols were tested to a standard glass reference material SRM 621 (NIST) in order to determine the most accurate and efficient protocol for the simultaneous multi-element analysis. The accuracy was evaluated by comparing the mean experimental concentrations with the corresponding certified values of the SRM material. In addition, the slopes of the calibration curves were used as a reliable criterion to evaluate the sensitivity, while the relative errors were used to estimate the accuracy of each procedure.

How procedures are developed – see there is always... I have told time and again that there is a necessity and for this necessity, there is a new invention. So, similarly, that is how science progresses. When there is no need, there is no science, because everything works on what has been already invented. But, every time, there is a new type of sample, a new type of matrix and it is felt that complete digestion has not taken place by the existing method, and new method is developed.

The aim of present lecture was to learn about a method for microwave-assisted wet-acid decomposition of the glass matrix, suitable for subsequent analysis by ICP-AES. It was felt that glass, which is the toughest to digest needs more attention, and therefore, there should be a new method of microwave-assisted wet-acid decomposition. For this purpose, a number of 13 acid mixtures containing HCl, HNO3 and HF were examined for their effectiveness in relation to two different microwave programs for pressure and temperature. So, the design of the method of microwave is now elaborated. You will see that two different programs were conducted in microwave analysis just the way we have cooking recipes. We cook [FT] in many ways; and, the [FT] is made in another way; and, there is some other amty, is made in a third way. Similarly, we have microwave-assisted programmed techniques for digestion, so that we see which one is better. In the case of food, it is the taste, which matters, but in this case, it is the best dissolution of all the components, which matters. I am giving you this day-to-day life example only to be able to correlate, although [FT] has nothing to do with microwave digestion of silicate samples.

Consequently, 26 microwave-assisted decomposition protocols were tested to a standard glass reference, that is, SRM 621, and this was listed in NIST library in order to determine the most accurate and efficient protocol for the simultaneous multi-element analysis. The accuracy was evaluated by comparing the mean experimental concentrations with the corresponding certified values of the SRM material. So, repeatedly, the different protocols were applied, different methods of microwave acid digestions were applied, and it was found that out of these method, which are the method, which give consistent result, because the standard reference glass sample SRM 621 has a very finite composition, and so, that is taken as a reference standard. So, the first analytical protocol was tested against this SRM 621 glass sample, and then, it was used as a reference standard for calibration method for the glass samples. In addition, the slopes of the calibration curves were used as a reliable criterion to evaluate the sensitivity, while the relative errors were used to estimate the accuracy of each procedure. So, the whole method was developed; it was a calibration method, which was then used for the new samples; whether it is archaeological sample or whether it is modern glass sample, was all compared with the reference sample SRM 621.

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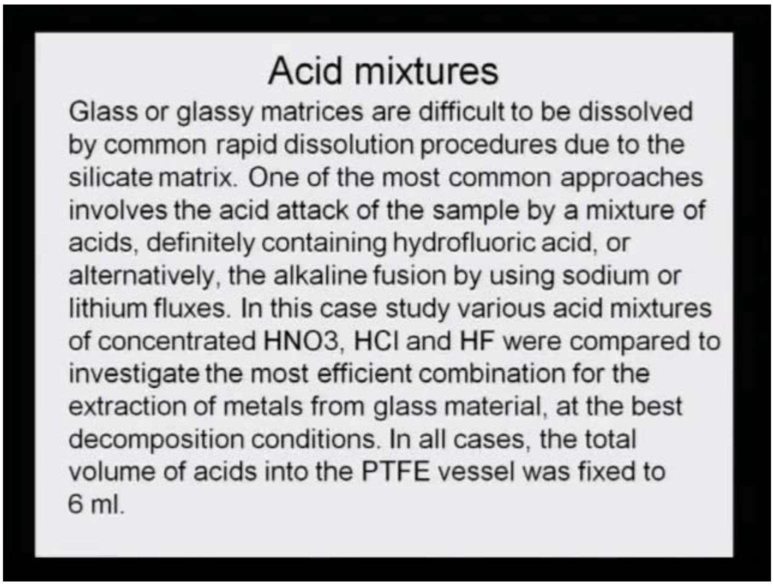

### Acid mixtures

Glass or glassy matrices are difficult to be dissolved by common rapid dissolution procedures due to the silicate matrix. One of the most common approaches involves the acid attack of the sample by a mixture of acids, definitely containing hydrofluoric acid, or alternatively, the alkaline fusion by using sodium or lithium fluxes. In this case study various acid mixtures of concentrated HNO3, HCl and HF were compared to investigate the most efficient combination for the extraction of metals from glass material, at the best decomposition conditions. In all cases, the total volume of acids into the PTFE vessel was fixed to 6 ml.

Acid mixtures – why there is a necessity for having such combination of acid mixtures? Glass and glassy matrices are difficult to be dissolve by common rapid dissolution processes due to the silicate matrix. Now, if we have suppose a metal or an alloy, it is very easy to digest in an open vessels simply by adding a little hot dilute nitric acid or hot dilute HCl, and the metal will completely come into the solution by acid digestion by merely heating little bit. But, that does not the story when we are analysing silicate matrices or glass sample. Why? Because they have a very complicated structure and a very tightly bound structure.

One of the most common approaches involving acid attack of the sample by a mixture of acids, definitely containing hydrofluoric acid, or alternatively, the alkaline fusion by using sodium or lithium fluxes was carried out. Now, there have been methods, which you may have come across in your BSc and MSc experiment that metals were analysed or certain compounds were analysed by sodium fusion; in place of sodium, even lithium fusion can be taken. That means the compound and a piece of sodium are kept side by side and then it is ignited. In the burning process of the sodium fusion, this gets into solution, and when water is added to this whole charged material, it is expected that all of it will come into solution form. But, that was not a very convenient method. That is why the use of hydrochloric acid was introduced. In this case studies, various acid mixtures of concentrated nitric acid, hydrochloric acid and hydrofluoric acid, were compared to investigate the most efficient combination for the extraction of metal from glass material. So, first, comparative data was created by using only hydrochloric acid, the traditional digestion acid, or by using nitric acid, which is also traditionally used or conventionally used for digestion of metals. But, it was found that not all the metal came into solution, and that is why, there was an introduction of hydrofluoric acid. But, the problem of using hydrofluoric acid is, that it cannot be used in glass beakers, because glasses are again made up of silicate and silicates react with hydrofluoric acid. So, then, what will happen, that it will digest the beaker also and the sample also. That is why these teflon vessels were brought into picture.

And, when it was investigated and found that which one is most efficient combination of extraction, it was found that the best decomposition conditions were – when all the three are used together. In all cases, the total volume of acid in the teflon PTFE vessel was fixed to 6 ml. It cannot exceed more than 6 ml, because vessels are slightly big, but there has to be a vacuum space to be able to handle the pressures of gas that are generated out of these acids. They are not all in liquid form, some of them are also in the vapour form, and if the liquid volume becomes large, then the total space that would be left will be small. So, that was kept in mind that these three acids, that is, the hydrochloric acid, the nitric acid and the hydrofluoric acid, must be taken in combination; first thing for the glass analysis or decomposition. And also, the total volume of these three acids, concentrated acids, should not exceed more than 6 ml volume.

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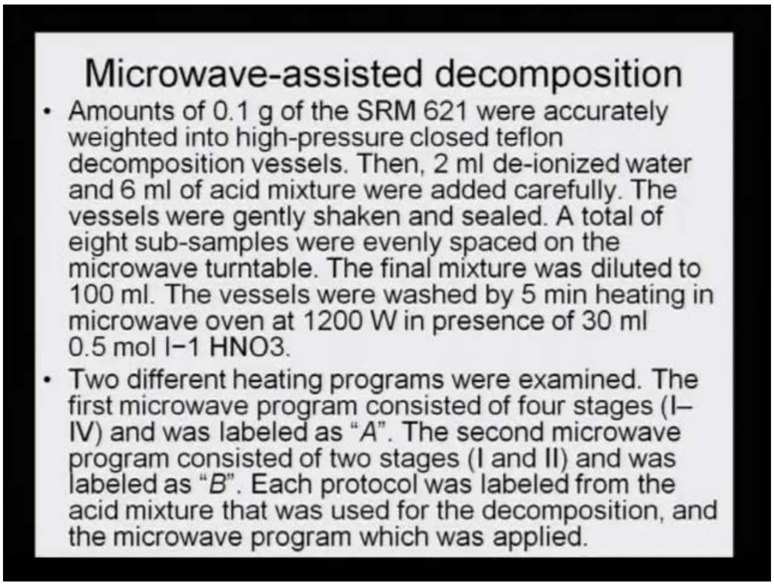

### Microwave-assisted decomposition

- Amounts of 0.1 g of the SRM 621 were accurately weighted into high-pressure closed teflon decomposition vessels. Then, 2 ml de-ionized water and 6 ml of acid mixture were added carefully. The vessels were gently shaken and sealed. A total of eight sub-samples were evenly spaced on the microwave turntable. The final mixture was diluted to 100 ml. The vessels were washed by 5 min heating in microwave oven at 1200 W in presence of 30 ml 0.5 mol l−1 HNO3.
- Two different heating programs were examined. The first microwave program consisted of four stages (I–IV) and was labeled as “*A*”. The second microwave program consisted of two stages (I and II) and was labeled as “*B*”. Each protocol was labeled from the acid mixture that was used for the decomposition, and the microwave program which was applied.

Microwave-assisted decomposition – amounts of 0.1 gram of the standard SRM 621 were accurately weighed into high pressure closed teflon decomposition vessels. Then, 2 ml of de-ionized water and 6 ml of acid mixture were added carefully. The vessels were gently shaken and sealed. A total of 8 sub-samples were evenly spaced on the microwave turntable. The microwave can hold 8 such vessels and in all the 8 vessels, there should be at least water or the samples dissolved in water; the turntable will not work if all the vessels are not fitted. And, to have an efficient absorption of microwave and no wastage of microwave energy being taken place, all these 8 teflon vessels, which are on a turntable in a microwave, should have water or the sample, which is digested with acids and water, because microwave energy only excites the water molecule, and that is how it helps in digestion. The final mixture was diluted to 100 ml. After the digestion has taken place, we can then increase the volume to 100 ml. The vessels were washed by 5 minutes heating in microwave at 1200 wattage in presence of 30 ml of 0.5 molar solution of nitric acid.

Two different heating programs were examined. The first microwave program consisted of 4 stage (1 to 4) and was labeled as A method. The second microwave program consisted of 2 stages (1 and 2) and was labeled as B method. Each protocol was labeled from the acid mixture that was used for the decomposition and the microwave program, which was applied. So, two different programs were carried out as what I mentioned in the earlier slide, and it was compared which method – whether the method A with 4 steps or the method B with just 2 steps – which one better for the complete digestion of this standard reference glass sample.

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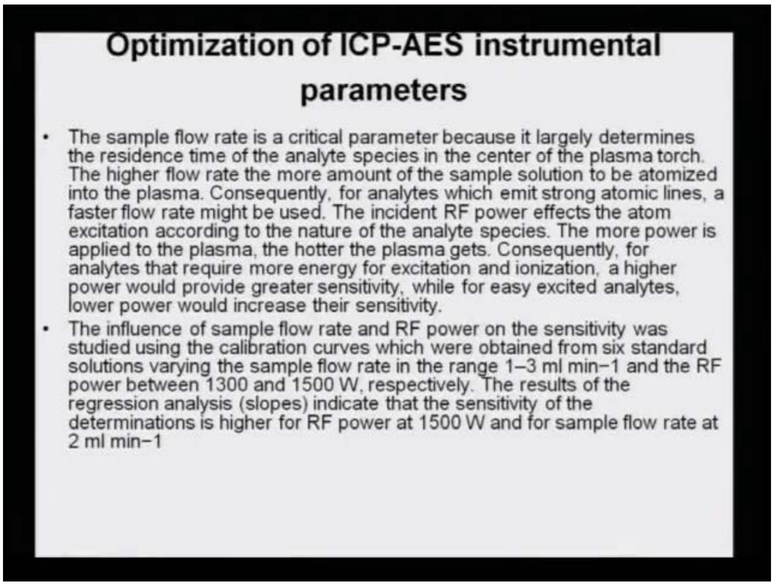

## Optimization of ICP-AES instrumental parameters

- The sample flow rate is a critical parameter because it largely determines the residence time of the analyte species in the center of the plasma torch. The higher flow rate the more amount of the sample solution to be atomized into the plasma. Consequently, for analytes which emit strong atomic lines, a faster flow rate might be used. The incident RF power effects the atom excitation according to the nature of the analyte species. The more power is applied to the plasma, the hotter the plasma gets. Consequently, for analytes that require more energy for excitation and ionization, a higher power would provide greater sensitivity, while for easy excited analytes, lower power would increase their sensitivity.
- The influence of sample flow rate and RF power on the sensitivity was studied using the calibration curves which were obtained from six standard solutions varying the sample flow rate in the range 1–3 ml min−1 and the RF power between 1300 and 1500 W, respectively. The results of the regression analysis (slopes) indicate that the sensitivity of the determinations is higher for RF power at 1500 W and for sample flow rate at 2 ml min−1

Optimisation of ICP-AES instrumental program – the sample flow rate is a critical parameter because it largely determines the residence time of the analyte species in the center of the plasma torch. The higher flow rate the more amount of sample solution to be atomised into the plasma. Consequently, the analytes which emits strong atomic lines, a faster flow rate might be used. The incident RF power effects the atom excitation according to the nature of the analyte species. The more power is applied to the plasma, the hotter the plasma gets. Consequently, for analytes that require more energy for excitation and ionization, a high power would provide greater sensitivity, while the easy excited analytes at low power would increase their sensitivity. So, here, there has to be certain instrumentational manipulation also.

I just told you the sample preparation needs manipulation and complete digestion. Similarly, there has to be some parameters that need to be adjusted according to the sensitivity and the presence at which they are in the solution while analysing on ICP-AES. And, what are these parameters? The incident RF power that effects the atom excitation, will also depends on the nature of the analyte species. More power will be applied for plasma to get hotter, so that more energy can be provided for excitation and ionisation, and greater sensitivity can be attained.

The influence of sample flow rate and RF power on sensitivity was studied using calibration curves, which were obtained from 6 standard solutions varying the sample flow rate in the range of 1 to 3 ml per minute and the RF power between 1300 to 1500 Watt, respectively. The results of the regression analysis, that is, the slopes indicate that the sensitivity of the determination is higher for RF power at 1500 wattage and for sample flow rate at 2 ml per minute is the optimum. So, these kind of optimisations that need to be carried out to be able to find out; it is not that only one method is designed and the new experiment is carried out on that one method, and it is found that this is the foolproof method. Nobody can say that this is the best method unless there is an optimisation. When we try to analyse, we need to carry out several methods and from those several new methods, then the best method is chosen to be used on a routine basis.

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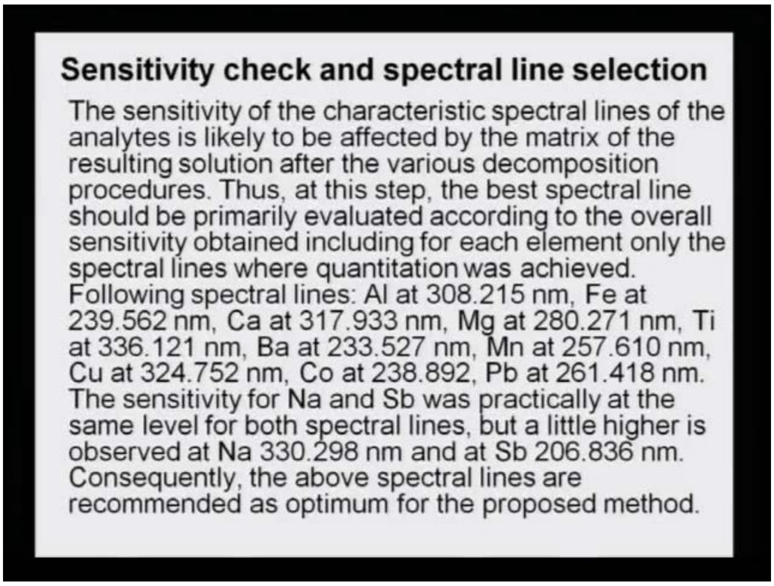

### Sensitivity check and spectral line selection

The sensitivity of the characteristic spectral lines of the analytes is likely to be affected by the matrix of the resulting solution after the various decomposition procedures. Thus, at this step, the best spectral line should be primarily evaluated according to the overall sensitivity obtained including for each element only the spectral lines where quantitation was achieved. Following spectral lines: Al at 308.215 nm, Fe at 239.562 nm, Ca at 317.933 nm, Mg at 280.271 nm, Ti at 336.121 nm, Ba at 233.527 nm, Mn at 257.610 nm, Cu at 324.752 nm, Co at 238.892, Pb at 261.418 nm. The sensitivity for Na and Sb was practically at the same level for both spectral lines, but a little higher is observed at Na 330.298 nm and at Sb 206.836 nm. Consequently, the above spectral lines are recommended as optimum for the proposed method.

Sensitivity check and spectral line selection – I have been talking about spectral line selection only when we are discussing ICP. I said that if two elements have close spectral lines, it will not be able to determine whether it belongs to element A or whether it belongs to element B. In such a case, the element A is chosen as it is and for the element B, another spectral line away from it should be chosen, so that there are no spectral line interferences. The sensitivity of a characteristic spectral line of the analyte is likely to affect by the matrix of the resulting solution after various decomposition procedures. So, what happens, when different acids are added, the sensitivity also changes; it does not remain the same. Now, under the given compositional changes – because there are also these acids which are in the solution form, there has to be some other manipulations in terms of selection of the spectral lines. Thus, at this step, the best spectral line should be primarily evaluated according to the overall sensitivity obtained including for each element only the spectral lines where quantitation was achieved. So, that means that whichever spectral line represents that particular element highly, that should be chosen. So, here again, there are some manipulations that need to be done for such a program and complicated analyses of glass samples.

Following spectral lines such as for aluminium, 308.215 nanometer was chosen; for iron, it was at 239.521 nanometer; for calcium, it was at 317.933 nanometer; for magnesium, 280.271 nanometer; for titanium, it was chosen at 336.121 nanometer; for cobalt, it was at 238.892 nanometer; for led, it was at 261.418 nanometer. Now, you see, they are fairly between the range of 308 to 261 and 233; different spectral lines for different elements were specifically chosen. The sensitivity for sodium and antimony was practically at the same level for both spectral lines, but a little higher is observed at sodium 330.298 nanometer and for antimony, it was 206.836 nanometer. So, that is why, since they were very close originally, two different clients were chosen for sodium and antimony, so that they can be separated out, and there should not be any confusion whether this line and this concentration belongs sodium or antimony. Consequently, the above spectral lines were recommended as an optimum proposed method. So, this was finally concluded, that aluminium at 308, iron at 239, calcium at 317, magnesium at 280, titanium at 336, barium at 233, manganese at 257, copper at 324, cobalt at 238, lead at 261, and for sodium 330 and antimony 206 were the final chosen spectral lines for this glass analysis.

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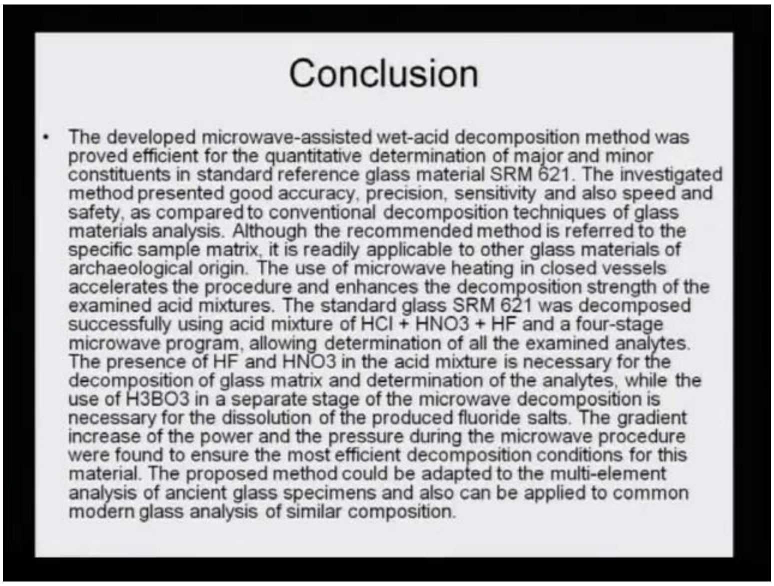

## Conclusion

- The developed microwave-assisted wet-acid decomposition method was proved efficient for the quantitative determination of major and minor constituents in standard reference glass material SRM 621. The investigated method presented good accuracy, precision, sensitivity and also speed and safety, as compared to conventional decomposition techniques of glass materials analysis. Although the recommended method is referred to the specific sample matrix, it is readily applicable to other glass materials of archaeological origin. The use of microwave heating in closed vessels accelerates the procedure and enhances the decomposition strength of the examined acid mixtures. The standard glass SRM 621 was decomposed successfully using acid mixture of HCl + HNO3 + HF and a four-stage microwave program, allowing determination of all the examined analytes. The presence of HF and HNO3 in the acid mixture is necessary for the decomposition of glass matrix and determination of the analytes, while the use of H3BO3 in a separate stage of the microwave decomposition is necessary for the dissolution of the produced fluoride salts. The gradient increase of the power and the pressure during the microwave procedure were found to ensure the most efficient decomposition conditions for this material. The proposed method could be adapted to the multi-element analysis of ancient glass specimens and also can be applied to common modern glass analysis of similar composition.

Conclusion – the developed microwave-assisted wet-acid decomposition method was proven to be most efficient for the quantitative determination of major and minor constituents in standard reference glass material SRM 621. The investigated method presented good accuracy, precision, sensitivity, and also speed and safety as compared to conventional decomposition techniques of glass material analysis. Although the recommended method is referred to as specific sample matrix, it is readily applicable to other glass materials of archaeological origin. That means it is a method, which is not only for reference sample, but it is also meant for modern glass samples and old time ancient glass samples. So, it is a method for all types of glass samples; complicated and very intricate analytical method has been developed.

The use of microwave heating in closed vessel accelerates the procedure and enhances the decomposition strength of the examined acid mixtures. The standard glass SRM 621 was decomposed successfully using acid mixtures – hydrochloric acid, nitric acid and hydrofluoric acid, and a 4-stage microwave program, allowing determination of all the examined analytes was carried out. The presence of hydrofluoric acid and nitric acid in the acid mixture is necessary for the decomposition of glass matrix as what I mentioned. Again and again, I am mentioning, because silicates are very tough to analyse and to decompose, and determination of the analytes were carried out, while the use of hydroboric acid in a separate stage of the microwave decomposition is necessary for the dissolution of the produce fluoride salts. So, first, when it is reacted with HF, it converts into fluoride, and then, the boric acid further dissolves the fluorides. The gradient increase of the power and the pressure during the microwave procedure were found to ensure the most efficient decomposition conditions for this material. The proposed method could be adapted for the multi-element analysis of ancient glass specimens and also can be applied to common modern glass analysis of similar composition. So, it is a method which has been found to be foolproof for all types of glass samples.

Then, coming to the use of ICP in pharmaceutical and biomedical analysis, as I said, every time, there is a new type of sample, which has complicated matrix. There is a challenge for the analyst to design a method, which should extract all the ingredients, and therefore, only the efficient analysis or data can be obtained.

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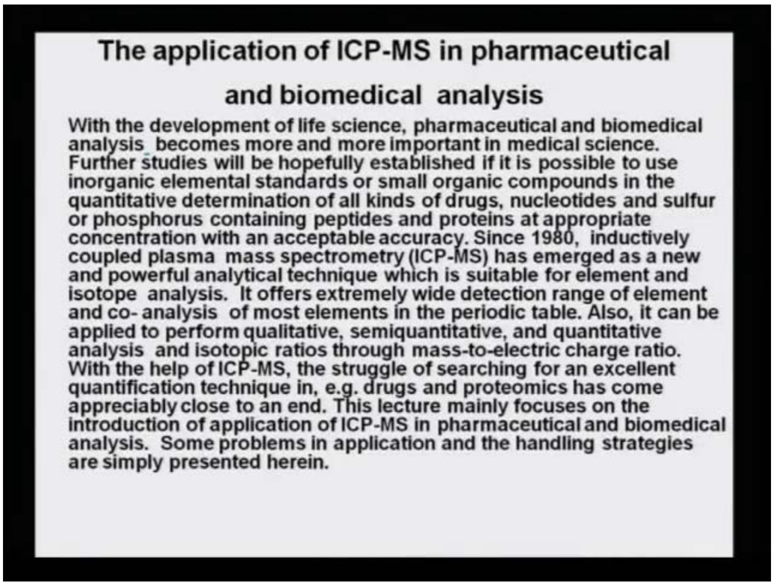

## The application of ICP-MS in pharmaceutical and biomedical analysis

With the development of life science, pharmaceutical and biomedical analysis becomes more and more important in medical science. Further studies will be hopefully established if it is possible to use inorganic elemental standards or small organic compounds in the quantitative determination of all kinds of drugs, nucleotides and sulfur or phosphorus containing peptides and proteins at appropriate concentration with an acceptable accuracy. Since 1980, inductively coupled plasma mass spectrometry (ICP-MS) has emerged as a new and powerful analytical technique which is suitable for element and isotope analysis. It offers extremely wide detection range of element and co- analysis of most elements in the periodic table. Also, it can be applied to perform qualitative, semiquantitative, and quantitative analysis and isotopic ratios through mass-to-electric charge ratio. With the help of ICP-MS, the struggle of searching for an excellent quantification technique in, e.g. drugs and proteomics has come appreciably close to an end. This lecture mainly focuses on the introduction of application of ICP-MS in pharmaceutical and biomedical analysis. Some problems in application and the handling strategies are simply presented herein.

With the development of life sciences, pharmaceuticals and biomedical analysis, it becomes more and more important in medical science, to be able to utilize these techniques and to analyse the analyte. Further studies will be hopefully established if it is possible to use inorganic elemental standards or small organic compounds in the inorganic standards, and quantitatively be able to determine all the kinds of drugs, nucleotides and sulfur or phosphorus containing peptides and proteins at appropriate concentrations with an acceptable accuracy.

Since 1980, inductively coupled plasma mass spectrometry, that is, ICP-MS has emerged as a new and powerful analytical technique, which is suitable for element and isotope analysis. It offers extremely wide detection range of element and co-analysis of most elements in the periodic table. Also, it can be applied to perform qualitative, semiquantitative and quantitative analysis, and isotopic ratios through mass-to-electric charge ratio; that is, with the help of the MS. With the help of ICP-MS, the struggle of searching for an excellent quantification technique in the examples like drugs and proteomics has become appreciably close to an end. This lecture mainly focuses on the introduction of application of ICP-MS in pharmaceutical and biological analysis method. Some problems in application and handling strategies are simply presented here.

So, how this ICP and the ICP-MS can be efficiently use for pharma samples or biomedical samples? What are the manipulations that required to be done? You know the basic working of ICP and the ICP-MS, but there are – just the way we saw for glass samples, some digestion method had to be a new method. Similarly, how to handle these type of sample, we will take a look at it.

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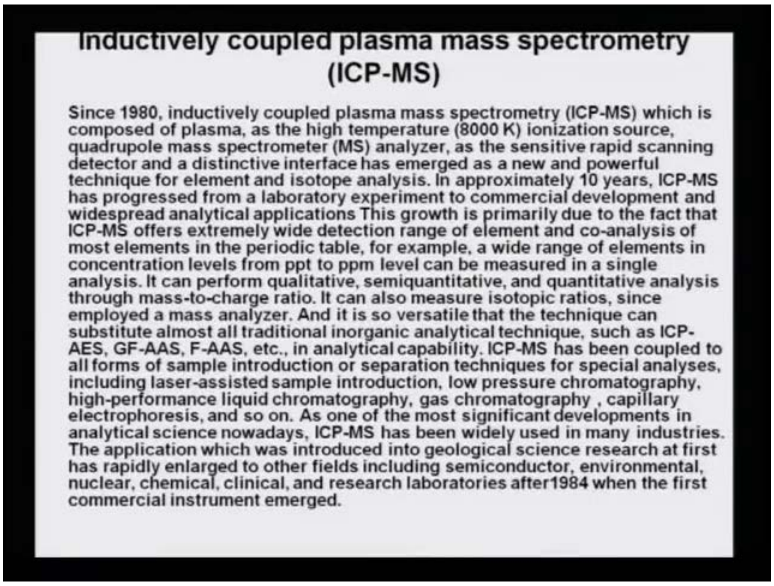

## Inductively coupled plasma mass spectrometry (ICP-MS)

Since 1980, inductively coupled plasma mass spectrometry (ICP-MS) which is composed of plasma, as the high temperature (8000 K) ionization source, quadrupole mass spectrometer (MS) analyzer, as the sensitive rapid scanning detector and a distinctive interface has emerged as a new and powerful technique for element and isotope analysis. In approximately 10 years, ICP-MS has progressed from a laboratory experiment to commercial development and widespread analytical applications This growth is primarily due to the fact that ICP-MS offers extremely wide detection range of element and co-analysis of most elements in the periodic table, for example, a wide range of elements in concentration levels from ppt to ppm level can be measured in a single analysis. It can perform qualitative, semiquantitative, and quantitative analysis through mass-to-charge ratio. It can also measure isotopic ratios, since employed a mass analyzer. And it is so versatile that the technique can substitute almost all traditional inorganic analytical technique, such as ICP-AES, GF-AAS, F-AAS, etc., in analytical capability. ICP-MS has been coupled to all forms of sample introduction or separation techniques for special analyses, including laser-assisted sample introduction, low pressure chromatography, high-performance liquid chromatography, gas chromatography , capillary electrophoresis, and so on. As one of the most significant developments in analytical science nowadays, ICP-MS has been widely used in many industries. The application which was introduced into geological science research at first has rapidly enlarged to other fields including semiconductor, environmental, nuclear, chemical, clinical, and research laboratories after1984 when the first commercial instrument emerged.

Inductively coupled plasma mass spectrometry – since 1980, inductively coupled plasma mass spectrometry, that is, ICP-MS, which is composed of plasma, as the high temperature (8000 kelvin) ionization source with the quadrupole mass spectrometer analyser, as the sensitive rapid scanning detector and a distinctive interface has emerged as a new and powerful technique for element and isotope analysis. In approximately 10 years time, ICP-MS has progressed from a laboratory experiment to commercial development and widespread analytical applications. So, you see, over a period of time, it has become so popular. This growth is primarily due to the fact that ICP-MS offers extremely wide detection range of element and co-analysis of most elements in the periodic table. For example, a wide range of elements in the concentration levels from ppt to ppm level can be measured in a single analysis. So, whether it is parts for trillium or whether it is parts per million, at every range, ICP-MS can be used.

It can perform qualitative, semiquantitative and quantitative analysis through the mass-to-charge ratio. That means if we want to find out whether it is present or not any element, or in what kind of relative presence they are there, or in absolute terms, how much of every element is present. All qualitative, semiquantitative and quantitative analysis can be carried out and that is because of this mass spectrometer analyser, which is highly sensitive and it is the quadrupole analyser, which takes care of the mass-to-charge ratio, and that is how it analyses. And, it is so versatile that the technique can substitute almost all traditional inorganic analytical technique, such as ICP-AES, graphite furnace-AAS and flame-AAS, etcetera in analytical applicability. So, that means for these biological and pharma samples, the only answer for analytical tool is ICP-MS, because it can replace all others and it is definitely far more superior. When I was showing you those graphs, I did show you the supremacy of ICP-MS; it was far beyond the graphite furnace or the ICP-AES, and of course, certainly, with the flame-AAS, which has no comparison between the other three.

ICP-MS has been coupled to all forms of sample introduction or separation techniques or for spectral analysis including the laser-assisted sample introduction, low pressure chromatography, high-performance liquid chromatography, gas chromatography, capillary electrophoresis, and so on. So, it can be coupled with every such instrument, and therefore, all separated components can be directly linked into the ICP-MS. As one of the most significant developments in analytical science, nowadays, ICP-MS has been widely used in many industries. The application which was introduced into geological science research at first who has rapidly enlarged to others fields including semiconductors, environmental, nuclear, chemical, clinical, research laboratories after 1984 when the first commercial instrument emerged. So, you see now, ICP-MS has a wide range of application. It can be used for semiconductors, for environmental samples, for nuclear science samples, for chemical science samples, clinical samples and research samples.

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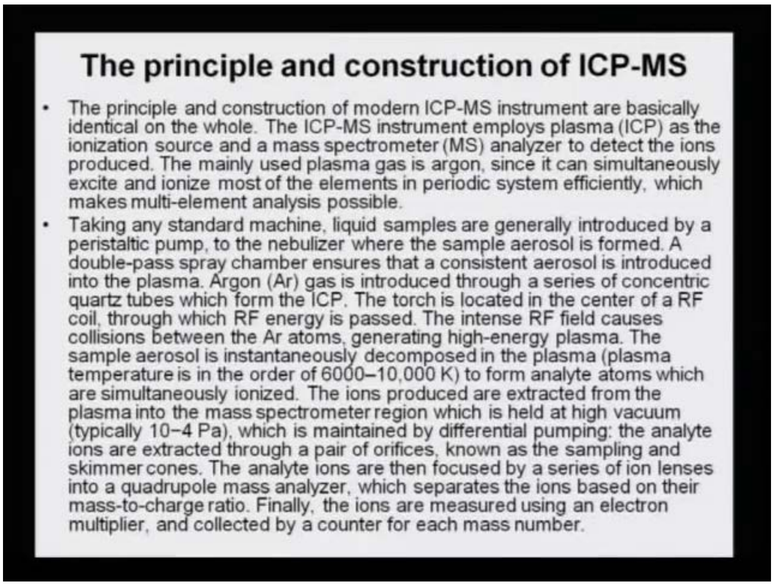

## The principle and construction of ICP-MS

- The principle and construction of modern ICP-MS instrument are basically identical on the whole. The ICP-MS instrument employs plasma (ICP) as the ionization source and a mass spectrometer (MS) analyzer to detect the ions produced. The mainly used plasma gas is argon, since it can simultaneously excite and ionize most of the elements in periodic system efficiently, which makes multi-element analysis possible.
- Taking any standard machine, liquid samples are generally introduced by a peristaltic pump, to the nebulizer where the sample aerosol is formed. A double-pass spray chamber ensures that a consistent aerosol is introduced into the plasma. Argon (Ar) gas is introduced through a series of concentric quartz tubes which form the ICP. The torch is located in the center of a RF coil, through which RF energy is passed. The intense RF field causes collisions between the Ar atoms, generating high-energy plasma. The sample aerosol is instantaneously decomposed in the plasma (plasma temperature is in the order of 6000–10,000 K) to form analyte atoms which are simultaneously ionized. The ions produced are extracted from the plasma into the mass spectrometer region which is held at high vacuum (typically 10−4 Pa), which is maintained by differential pumping: the analyte ions are extracted through a pair of orifices, known as the sampling and skimmer cones. The analyte ions are then focused by a series of ion lenses into a quadrupole mass analyzer, which separates the ions based on their mass-to-charge ratio. Finally, the ions are measured using an electron multiplier, and collected by a counter for each mass number.

The principle and construction of ICP-MS – the principle construction of modern ICP instruments are basically identical on the whole. There is no main change. There is an ICP, which implies plasma and that is why the name ICP for its ionization source, and there is a mass spectral analyser. So, that is all that the machine has. But, the standard of introducing the sample, the procedure for using different types of nebulizers, these vary in an ICP-MS machine when the sample changes from one to another.