Proposition of Ph.D thesis

STUDY OF HIGH TEMPERATURE THERMAL PROCESSES WITH SPECTROMETRIC METHODS

Dávid Nagy

Supervisor: Dr. József Posta, university professor

University of Debrecen
PhD Program in Chemistry
Debrecen, 2013.

I. Introduction and the aim of work

One of the simplest and most evident way of examining thermal processes occurring at high temperature is the study of thermal reactions undergoing in different flames. Hydrocarbon flames used for analytical purposes can be characterized with its structure, temperature and chemical composition. The thermal conversions undergoing in flame are in one respect thermochemical processes, in other respect they are the products of reactions between the sample particles and flame radicals. Spectroscopists tend to develop such measuring methods, where the signal of the analyte is independent of chemical bonding environment, by this way samples with the same element concentration will give the same analytical signal despite the differences of substances.

According to an another approach of material testing, the change in the physical and chemical properties of a substance is studied as a function of temperature alteration. These methods, namely thermogravimetry (TG), derivative thermogravimetry (DTG), differential thermal analysis (DTA), etc. are referred as the methods of thermal analysis (TA). Thermal analysis with its centuries-old history is of great importance in material sciences, in analytical research and in the study of minerals, inorganic substances, electronic parts, polymers, organic substances, organic materials, pharmaceuticals and biological organisms, respectively.

The appearance of TA - coupled techniques are important milestones in understanding of thermal processes. With the expansion of application field of thermal analysis it was soon realized, that additional valuable information can be achieved by complementary techniques. For instance the evolved gases formed in thermal reactions became determinable by thermal analysis-mass spectrometry. Fourier infrared spectroscopy and gas chromatography are further complementary techniques.

The potential of TA would be increased if the direct analysis of liquids, solutions and gases -beside solid samples- were commercially available. Efforts have already been made for the analysis of substances, although they can only be performed under special circumstances. The time consumption of TA measurements can not be reduced under a certain limit in spite of the mentioned developments. The moment-like, in-situ analysis of the whole spectra of thermal processes is not possible yet. There is an increasing demand for the study of chemical and physical properties of nanoparticles at different temperatures. Furthermore, TA methods do not provide sufficient information about the formation and decomposition of ground state and excited state molecules, atoms and ions.

The chemical reactions between sample particles and the reactive components of the high temperature media, moreover the pure thermal decomposition processes have been intensively studied in our research group in the last 30 years. Attempts have been made to study separately these reactions and processes with the methods of conventional thermal analysis (TG, TG-MS, DTG, DTA), and with the methods of atomic spectrometry (arc and sparc excitation spectroscopy, flame and graphite furnace atomic absorption spectrometry, inductively coupled plasma – optical emission spectrometry), respectively.

The final aim of my method development is to establish a new material testing method by the combination of thermal analysis and spectrometry, that broadens the potential of conventional thermal analytical techniques, while it provides for spectrometry the possibility to study new substances that was difficult or impossible earlier. Consequently, new analytical techniques can be derived from thermospectrometry.

In my doctoral research work my basic goal was to determine the rate of contribution of two proceedings to the atomization of sample in hydrocarbon flames, which are the following: one is the pure thermal processes occurring at high temperature and the other is the chemical reactions undergoing with the present reactive radicals. For this purpose the following techniques have been developed:

1. Use of highly reducing flame. The reaction zone of this type of flame contains reactive radicals in significantly smaller concentration compared to stoichiometric flame.
2. Use of separated three slot burner which guarantees the sample particles to enter the flame in the radical lean burnout zone, by this way avoiding the reaction zone.
3. Sample aerosol is separated from flame radicals by a wall. In this case the sample moves in a quartz tube in argon atmosphere

heated externally by the flame. As a result the contribution of radical reactions to atom formation is excluded.

4. The planning and construction of a unique instrument named *thermospectrometer* was implemented by using the experiences gained for variant samples from the above mentioned methods. The new method is the combination of thermal analysis and spectrometry, which is intended to be used for the analysis of water soluble, volatile substances that are less studied with thermal analysis.

II. The applied measuring methods

For the experiments carried out in hydrocarbon flames a Unicam SP1900 atomic absorption spectrometer was used. For the special atomic distribution measurements a custom-made three slot burner was used, where the sample aerosol and flame gases emerge through different slots. Both the Unicam burner and both the separated three slot burner was positioned in horizontal and vertical directions by the help of a stepper motor in a 30-30 cm long way. The thermospectrometer was connected with a Unicam SP9 AAS instrument through solar resistant Avantes optical fibers. Data acquisition was established with an analogous/digital converter connected to the signal output port of AAS instrument and with a simple program developed in National Instruments LabView environment. For sample introduction a conventional pneumatic concentric nebulizer and hydraulic high pressure nebulizer (HHPN) were used. The aerosol was led through a custom-made Des-03 type desolvation system, where the solvent is evaporated and separated from analyte, by this way dry aerosol is introduced to the furnaces.

III. New scientific achievements

A) Construction part

1. Development of separated three slot burner

1. proposition: The separated three slot burner has been constructed where the sample particles are atomized in the burnout zone of the flame avoiding the reaction zone

Separated three slot burner was constructed, which differs in structure and functioning from conventional 5 cm long slotted acetylene/air burner, that the middle slot is connected to a separate chamber instead of the nebulizer chamber of AAS instrument. The sample aerosol leaves the burner through its middle slot. The acetylene/air mixture emerges and burns through two slots on the two sides of the middle sample slot of the burner. As a result the sample avoids the direct contact with the reaction zone of the flame. By this way the thermal conversion processes occur in the burnout zone of the flame which is leaner in reactive radicals. The cross section of the special burner is depicted in Fig. 1.

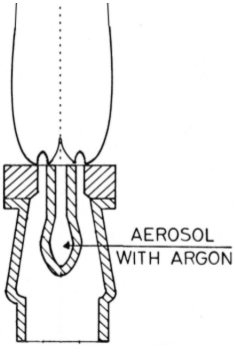

Figure 1. Separated three slot burner

2. Development of quartz flame furnace

A special tool, quartz flame furnace has been developed to completely prevent the interaction between sample particles and reactive flame particles. A special burner has been constructed which is compatible with the burner support of a conventional AAS instrument. The sample aerosol leaves the burner through a hole with a diameter of 2 mm which is located in the center of the burner. The hole is surrounded by a perpendicular quartz tube. The flame burns on a round channel around the quartz tube. By this way the sample particles do not get in contact with flame composing radicals, the flame has only heating role in the atomization process. The light of the atomic absorption light source is led through the quartz tube in the symmetry plane of the sample stream. Moving the furnace up and down, the thermal decomposition processes can be followed as a function of height.

2. proposition: The flame in case of quartz flame furnace has only heating role, it does not get in contact with the sample. By this way pure decomposition processes free from the influence of reactive flame particles are followed.

The preliminary results confirmed that the height of the quartz tube has significant effect on the way of sample aerosol flow. The sample stream can not retain the bore diameter developed at the emergent aperture above a certain tube height, on the contrary, it spreads out and completely fills the tube in a chaotic motion. The main reason might be the following: when a gas flows upward along the vertical axis of a tube, at the top of the tube suction effect can emerge along the inner walls of the tube. It means outside atmosphere can enter the tube from the top, which contaminates the originally inert internal atmosphere. To eliminate this problem, the quartz flame furnace has been reconstructed to a double-wall arrangement as shown in Fig. 2. The two concentric tubes are fused together at the top. Between the two tubes argon is introduced through a side-tube that flows downwards. At the plane of the burner it turns inside the inner tube, where it helps the sample aerosol leaving the system, and simultaneously it prevents the outer atmosphere to enter the tube at the top.

The quartz tube is vitrified in acetylene/air flame after a longer period of time of usage. As it is turning opalic, the capability of light transparency is decreasing. To eliminate this problem, instead of acetylene/air flame, propane-butane − air flame was used. This flame contains less reactive components, by this way the quartz glass remains transparent to light. The temperature distribution in the symmetry axis of the tube was determined by an S-type Pt - Pt/Rh thermocouple along the height of the tube. With propane-butane − air heating flame the operational temperature inside the furnace is 550 - 650 °C, which is only 100 °C lower than that of using acetylene-air heating flame. The rate of flushing gas for the nebulization was kept at 0.5 L/min.

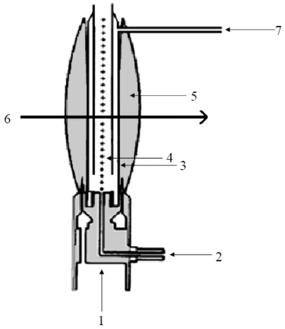

Figure 2. Scheme of quartz flame furnace. 1) flame gases, 2) sample input, 3) quartz tube, 4) sample aerosol, 5) heating flame, 6) spectral light beam, 7) auxiliary gas

The application of quartz flame furnace has limitations. The thickness of atomic cloud inside the tube is approximately ten times smaller than in a 5 cm slotted burners flame. By this way ten times higher analyte concentration has to be used for the study of atomization. An another limitation is that the observation height can be altered in 0 - 45 mm range in case of original burner systems. Furthermore the temperature of the furnace is a given value, it can only be influenced slightly by changing the ratio of flame gases. The termination of these limitations inspired us to plan and develop a new material testing method, called thermospectrometry.

Development of thermospectrometry

Proposition 3: Conversion processes occuring separately in time and space can be studied with spectrometric methods in the stationary furnace of the thermospectrometer under controlled composition atmosphere along the 200 mm height of the furnace.

The central unit of the thermospectrometer is a special stationary furnace which can be heated in a regulated way up to 1750 °C. It consists of two heated, parallel silicon carbide plates placed 10 mm far from each other. Between the plates nanoparticles of solids or liquids or gas molecules flow upwards. The temperature along the height of the furnace is constant, by this way the thermal decomposition of sample particles occurs in different ways separated in time and space depending on their thermal properties. The formation of molecules, atoms and ions during the thermal conversion can be followed directly with narrow light beam of the spectral lamps along the 200 mm height of the furnace. The scheme of thermospectrometer can be seen in figure 3.

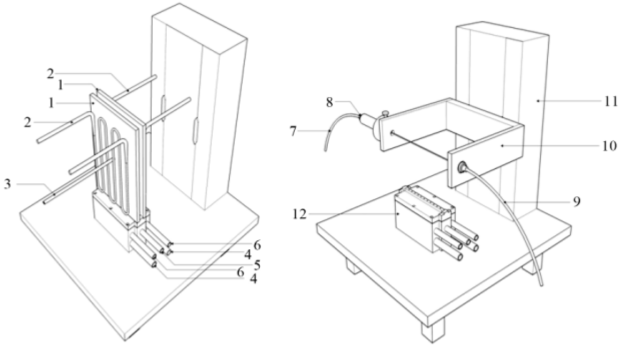

Figure 3. Structure of thermospectrometer. 1) silicon carbide heated plates, 2) heating filaments, 3) temperature controlling thermocouple, 4) fitting for cooling water, 5) sample inlet fitting, 6) auxiliary gas connection, 7) optical fiber connecting the light source and furnace, 8) acromatic lens system, 9) optical fiber connecting the light source and furnace, 10) optical fiber positioning framework, 11) stepper motor

The introduced dry sample aerosol flows upwards between the plates in a laminar, stationary flow. The conversion processes can be followed with different spectroscopic techniques (scattering of light, UV-Vis, IR, AAS, OES). The light of the spectral light source is led to the furnace and back to the monochromator with solar resistant optical fibers. These fibers are mounted to a framework that is positioned vertically with a stepper motor.

One of the critical conditions of the long-term reliable and stable operation of the thermospectrometer is that the sample stream should flow in the symmetry plane of the furnace and it should retain its emerging shape throughout the whole height of the furnace by not touching the silicon carbide walls. To secure the laminar flow of sample stream, along the inner walls of the furnace an auxiliary gas was introduced based on the experiences gained in quartz flame furnace experiments. The auxiliary gas was introduced at the top of the furnace behind the walls. The heating filament preheats the gas, which turns inside to the sample region under the lifted silicon carbide walls.

The sample was introduced to the furnace with hydraulic high pressure nebulizer. The advantage of this nebulization against pneumatic nebulization is the greater nebulization efficiency, furthermore the nebulization does not require nebulizing gas. Thus the formed aerosol can be flushed out from the aerosol chamber with a carrier gas at any flow rate. By this way the residence time of sample particles in the furnace can be changed in a wide range.

Preliminary results showed that the direct introduction of aerosol to the furnace is not favorable since the drying of droplets would occur at higher regions of the furnace, by this way the residence time would be insufficient for further decomposition processes to occur. To eliminate this problem, the sample aerosol is led through a desolvation system prior to entering the furnace. By this way dry sample nanoparticles are introduced to the thermospectrometer.

B) Atomization of mercury and cadmium salts under reactive and inert circumstances

4. Atomization of cadmium salts in flame and quartz flame furnace

The atomization properties of cadmium salts (acetate, chloride, nitrate, perchlorate, sulphate) are quite favorable in acetylene-air flame. This is confirmed by the fact that the atomization of cadmium salts is independent of the physical-chemical properties of the substances even in the direct vicinity of reaction zone of oxidizing (C/O ratio = 0.3), stoichiometric (C/O ratio = 0.4) and reducing (C/O ratio = 0.7) flames. The atomic distribution of different salts in the lowest region of the flame is almost the same. The thermal decomposition processes and the atomization is independent of bonding environments in the presence of reactive flame radicals.

During the measurements carried out with three slot burner the atomization curves showed significant differences only at low observation heights which is credited to the avoidance of reaction zone containing reactive radicals in high concentration. The highest atom concentration was observed in case of cadmium chloride at 0-4 mm observation region, while the lowest atom concentration was provided by cadmium sulphate. Slight difference can be observed in the atomization of cadmium salts at observation heights larger than 4 mm. Cadmium chloride atomized the best, while cadmium acetate atomized the least throughout the whole height of the furnace. The other three salts (nitrate, perchlorate, sulphate) atomized for the same extent.

Proposition 4: Cadmium salts in the same concentration atomize at diverse rate and extent in the quartz flame furnace, in contrast with the conventional AAS techniques, where no difference can be made between the atomization of the these salts.

The atomization processes in the quartz flame furnace occurred through pure thermal decomposition processes under inert environment in the absence of reactive radicals. Cadmium chloride provided ground state atoms in the quartz flame furnace to the highest extent. It was followed by cadmium nitrate regarding the extent of atomization. The rate of atomization is smaller in case of acetate and sulphate, respectively. Remarkably cadmium perchlorate atomized for the lowest extent at this temperature. This is surprising when we take a look at the thermal behavior of perchlorates. Cadmium perchlorate gave quarter amount of free atoms than cadmium chloride.

5. Thermospectrometric study of mercury salts

A characteristics of conventional TA curves of mercury salts is that, at a few hundred °C the weight of the substance is reduced to zero in a narrow temperature range that means the whole sample is evaporated from the crucible. Thus it is hard to establish the thermal differences in TA curves of mercury compounds due to the high volatility of mercury substances. The detection of ground state atoms formed in the thermal processes is much more difficult. Thermospectrometry has a great importance in this filed, since it allows us to study and compare the extent and rate of atomization of mercury salts at different temperatures under inert atmosphere.

Proposition 5: The study of thermal decomposition and atomization of volatile mercury compounds is possible by thermospectrometer which experiments were unperformable with the previous methods.

An atomization thermospectrogram is featured by two important data. The first one is the height of furnace where atoms can be detected, the second one is the furnace height where the maximum concentration of the formed atoms is reached. These values depend on the thermochemical properties of the studied compounds, on the furnace temperature and on the residence time of the sample aerosol in the furnace, respectively. During analysis the residence time was kept constant by the control of the sample intake rate. The rate of atomization was controlled by changing the temperature of the furnace.

Proposition 6: Mercury salts atomize to divergent rate and extent in the thermospectrometer at the lowest, 0-3 mm observation height. The observed differences are directly connected to the thermal properties of the studied substances.

The atomic concentration in case of different mercury salts is not the same even at the lowest 0-3 mm observation heights.

During the measurements the light beam was kept at the lowest point of the furnace for a given time after the sample had been introduced. The first part of the thermospectrogram represents the extent of atomization of entering dry aerosol and the rate at which the signal turns to saturation in the 0-3 mm observation region. The light beam was kept for 60 seconds at the lowest point after the sample was introduced, then the stepper motor was started to study the atomic distribution along the whole height of the furnace.

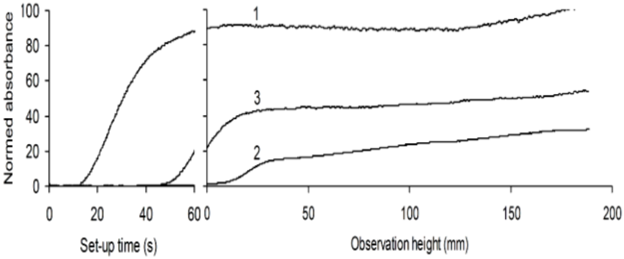

Figure 4. Atomic thermospectrograms of mercury(II) formate (1), acetate (2) and propionate (3) at 300 °C under inert atmosphere

Proposition 7: The order of the three mercury salts (Hg(II) format, acetate, propionate) at low temperatures is the same as the order of homologue series, regarding thermal stability. At 900 °C, however, the differences in the thermal properties of substances do not contribute to the atomization.

The thermal decomposition of Hg(II) formate, acetate and propionate is illustrated at 300 °C through the formation of mercury atoms (figure 4.). The first 60 s of the curves demonstrates well that the thermal behavior of the three organic mercury salts differ significantly. In the case of mercury(II) formate, the Hg atoms emerge as early as the 10th second after the start of sample introduction in the 0-3 mm observation height range. Hg(II) acetate produces free Hg atoms only after 50 s, while Hg(II) propionate does not give any free mercury atoms at this height.

During the vertical scanning of the furnace, the rate and tendency of atom formation is different in case of the three mercury salts. The concentration of mercury atoms formed from mercury(II) formate reaches quasi-saturation state even in the 0-3 mm observation height range, which remains constant up to approximately 150 mm observation height, where it starts to increase again until the end of the measurement. Atoms formed from mercury(II) acetate reach the quasi-saturation state at approximately 15 mm observation height, which shows slight increase through the entire height. This atom concentration, however, does not reach half of value observed with mercury(II) formate. The rate of atomization of mercury(II) propionate is much smaller. It starts at the height of 15 mm, and continuously increases. At the top of the furnace, it reaches only 30 % of the signal of mercury(II) formate.

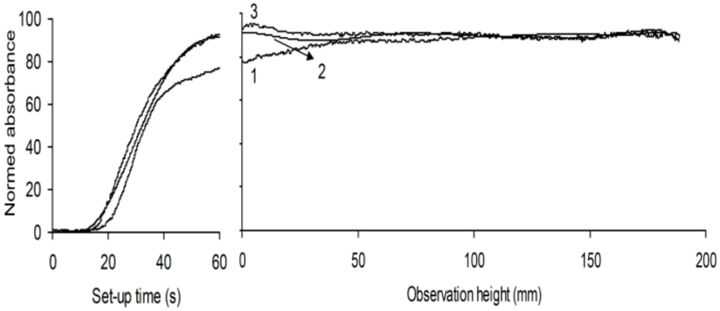

Figure 5. Atomic thermospectrograms of mercury(II) acetate (1), propionate (2) and formate (3), at 900 °C under inert atmosphere

Proposition 8: Mercury(II) thiocyanate atomized for the highest extent among the studied mercury pseudohalides ($K_2[HgI_2Br_2]$, $Hg(CN)_2$, $Hg(SCN)_2$) at each temperatures which is credited to its different decomposition atomization mechanism. The thiocyanate atomizes presumably through sulphide, which is a benefitial form for the liberation of mercury atoms.

The differences shown between the atomization of the previous mercury compounds practically disappear at 900 °C (figure 6.). The behavior of mercury(II) propionate with increasing temperature is remarkable. The rate of atomization of the propionate salt is the lowest throughout the entire height of the furnace compared to the formate and acetate salts. At 500 °C, however, the rate of atomization of the propionate salt precedes the acetate and at 900 °C, the propionate salt behaves similarly to formate salt, whereas the acetate salt tends to close up to them.

In an other series of experiment the atomization of mercury(II) pseudohalides was studied. The atomic thermospectrograms of potassium diiodo dibromo mercurate(II), mercury(II) cyanide and mercury(II) thiocyanate is shown in figure 6. measured at 700 °C in argon atmosphere. The atomization of the three inorganic mercury salts is different at each temperatures. The extent of atomization of mercury(II) thiocyanate is greater than that of the two other salts not only at 700 °C, but at each temperature. The possible reason of the different atomization of mercury thiocyanate is that it decomposes through sulphide in contrast with the other two salts. According to literature the liberation of mercury atoms is easier from sulphide then from halides, pseudohalides.

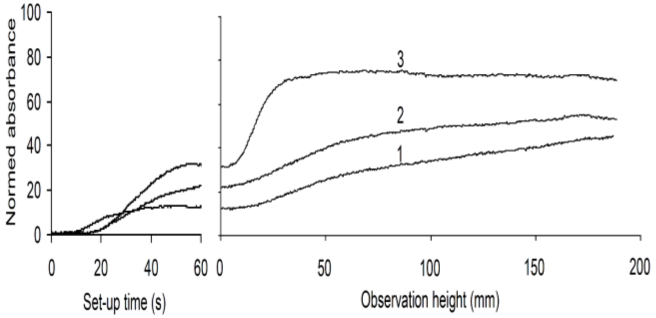

Figure 6. Atomization of mercury salts in the thermospectrometer at 700 °C under argon atmosphere: 1) potassium diiodo dibromo mercurate(II), 2) mercury(II) cyanide, 3) mercury(II) thiocyanate

6. Study of atomization of cadmium compounds in the thermospectrometer

Proposition 9: Cadmium salts under inert atmosphere do not produce ground-state free atoms in measurable quantity. At higher temperatures the atomic thermospectrograms can be described with a maximum-like curve.

The first apparent characteristics of atomization curves of cadmium compounds is the maximum curve-like atomic distribution that was not observed in the atomization of mercury compounds. Partly it can be credited to geometric reasons. As the cadmium aerosol proceeds upward in the furnace, it spreads out, by this way the atomic concentration in the cross-section of the light beam decreases. On the other hand, free cadmium atom consuming decomposition reactions might occur, however, we could not confirm it experimentally yet.

Proposition 10: The atomization of cadmium(II) perchlorate sarts swiftly at 700 °C, and with increasing temperature the rate and the extent of atomization is increased, respectively.

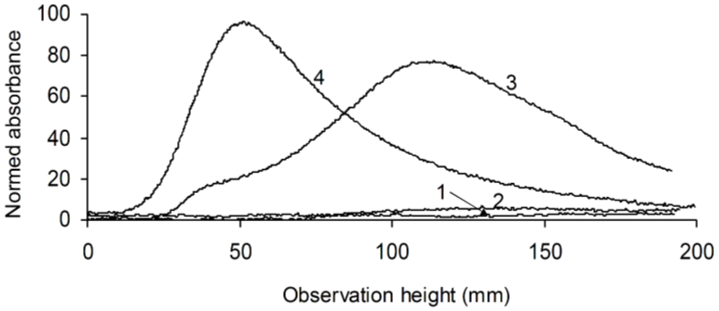

Figure 7. Atomization of cadmium(II) perchlorate in the thermospectrometer under argon atmosphere at different temperatures. 1) 600 °C, 2) 650 °C, 3) 700 °C, 4) 800 °C

The studied cadmium salts did not provide free atoms in detectable amount under 600 °C. The thermospectrometric behavior of cadmium salts is illustrated through the atomization of cadmium(II) perchlorate as shown in figure 7.

Similarly to the results of quartz flame furnace experiments, at 600 and 650 °C the extent of atom formation is quite small. When the temperature of the furnace was raised by 50 °C, however, the rate of cadmium atom formation at 700°C increased significantly. By further increase in temperature, at 800 °C the beginning of atomization of the sample demands less residence time that means the process starts in lower region of the furnace. While at 700 °C the atomization reaches maximum at 115 mm height, at 800 °C the maximum atomic concentration is attained at 50 mm observation height.

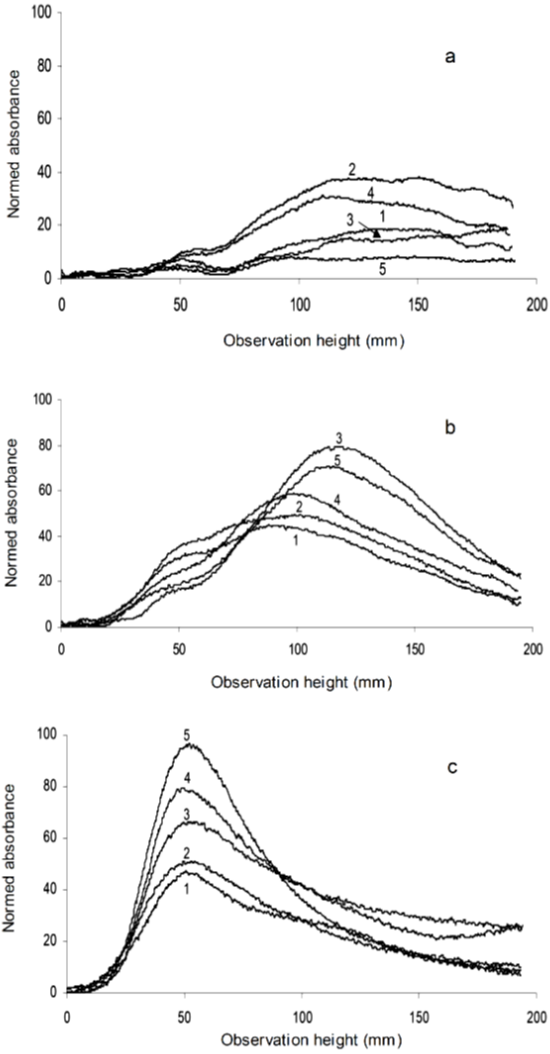

Figure 8. Atomization of cadmium salts at **a)** 650 °C, **b)** 700 °C and **c)** 800 °C 1) $CdCl_2$, 2) $Cd(Ac)_2$, 3) $Cd(NO_3)_2$, 4) $CdSO_4$, 5) $Cd(ClO_4)_2$

Proposition 11: The five studied cadmium salts (acetate, nitrate, chloride, perchlorate, sulphate) are atomized in the thermospectrometer by following two competiting reaction courses. Between 650-700 °C the atomization takes place primarily at hihger regions of the furnace, while at 800 °C the machanism occuring at 50 mm height is exclusively dominant.

The atomization behavior of five cadmium salts (chloride, acetate, nitrate, sulphate, perchlorate) was compared with the thermospectrometer as shown in figure 8. When the dry aerosol of the salts consisting of nanoparticles is led through the stationary furnace, they do not decompose significantly under argon atmosphere below 600 °C, since free ground state atoms were not detectable. The atomization of the salts become detectable at 650 °C, although the atom formation occurs in the higher regions of the furnace, since the atomization requires longer sample residence time in the furnace. At 50 mm height of the furnace a small local peak can be observed which is the sign of a competing decomposition mechanism. This decomposition mechanism occurring at 50 mm height of the furnace becomes more dominant at 700 °C, however the majority of the cadmium atoms are still formed at higher heights of the furnace. At 800 °C the formation of cadmium atoms occurs exclusively according to the faster decomposition mechanism. The ratio of the two competing mechanisms is different for each cadmium salts depending on their material properties.

This might explain the difference in rate and order of atomization between the salts at 650 and 800 °C. While cadmium acetate atomizes the best and cadmium perchlorate atomizes the least at 650 °C, at 800 °C the order of atomization changes to opposite, perchlorate atomizes the best and the acetate atomizes the least similar to chloride.

The following general conclusion can be drawn from my studies performed with different measuring systems: when the contribution of reactive particles to atomization is excluded, the differences in thermal properties of substances gets more and more determinant. The order of atomization of cadmium salts at 800 °C in the thermospectrometer shows good correlation with the order of salts based on their melting temperatures.

IV. Possible application of the results

Both the quartz flame furnace and electrically heated thermospectrometer is capable for the study of thermal properties of substances based on new principles. They might contribute to the experimental determination of bonding environment in material testing sciences.

Thermospectrometry might play an important role in the understanding of the mechanism of high temperature processes, like atomization. The mechanism of analytical interfering effects generally observed in high temperature media (in flame, graphite furnace or gas plasma) can be explored.

Thermospectrometry do not exchange the methods of conventional thermal analysis, on the contrary, it completes them. It can confirm or disprove our existing knowledge regarding the thermal decomposition of materia.

The study of pyrolysis of organic substances and the detection of the formed gaseous molecules become possible when the thermospectrometer is coupled with molecule spectrometric techniques (UV-VIS, IR spectrometry). By this way valuable information can be gained for instance about modelling of waste incineration or about moderation of cracking of hydrocarbon derivatives. For these purposes it would be most convenient if the thermospectrometer were coupled with an atom and molecule spectrometric instrument equipped with continuous light source. By this means the light scattering, molecule and atomic spectrometric measurements could be performed with one single instrument.

Since nanoparticles are travelling through the controlled heating furnace of thermospectrometer, the instrument might be feasible for the continuous preparation and collection of different nanoparticles when the collection of the leaving product is solved.

Thermal processes can be studied not only under inert, but under reactive atmosphere by changing the composition of aerosol flushing gas and auxiliary gas.

As far as the cross-lighting of the whole analytical observation height and the signal processing is realized at the same time, the thermospectrometer becomes suitable for speciation analysis. Substances with diverse thermal properties decomposes at different heights of the furnace, by this way the species of an element can be studied in a solution without the use of expensive chromatographic techniques.

The number of possible elements to be analyzed will expand with the increase of temperature. Even 2000-3000 °C temperature might be reachable in the thermospectrometer with the further improvement of the walls and heating filaments, which temperature range corresponds to the operation temperature of flame and graphite furnace spectrometry.

V. List of Publications

Articles connected to the thesis

1. D. Nagy, Cs. Falussy, J. Posta
Thermospectrometry – a new method to follow thermal processes with spectrometric methods
Journal of Thermal Analysis and Calorimetry, 2013, in press
DOI number: 10.1007/s10973-013-3254-5
Impact Factor: 1,604

2. D. Nagy, Cs. Falussy, A. Balogh, T. Nagy, J. Posta,
Atomization of cadmium compounds in inert and reactive high temperature environment with stationary sample introduction,
Applied Spectroscopy, 2013, in press
DOI number: 10.1366/13-07151.
Impact Factor: 1,663

3. Falussy Cs., Posta J., Nagy D.,
Development of method and instrument for the thermospectrometric study of thermal processes based on new principles
Office of National Intellectual Property
Case number: P1200587, University of Debrecen, 2013, Hungarian patent applied for

Articles not detailed in the thesis

1. Posta J., Nagy D., Béni Á., Kapitány S.
Study of liquid-liquid extraction, separation and enrichment mechanisms by atomic absorption spectrometer combined with continuous extraction device. Application of the method for chromium speciation
Anyagvizsgálók Lapja, 2007/3, pp.114-117
Paperless journal not assigned with Impact Factor

2. F. M. El Saih, Nagy D., Hegedus I., Posta J.
Indirect determination of sulphur dioxide and sulphuric acid by flame atomic absorption spectrometry.
Studia Universitatis Vasile Goldis Arad – Seria Stiintele Vietii (Life Sciences Series), 2010, 20:(3) pp. 59-63.
Impact Factor: 0,185

3. Beni A, Nagy D, Kapitany S, Posta J
Development of chromium speciation methods for environmental samples
Studia Universitatis Vasile Goldis Arad – Seria Stiintele Vietii (Life Sciences Series), 2011, 21:(1) pp. 77-80.
Impact Factor: 0,139

4. E. Baranyai, D. Nagy, I. Tóth, J. Posta
The environmental and morphologycal analysis of urban dust.
Studia Universitatis Vasile Goldis Arad – Seria Stiintele Vietii (Life Sciences Series), 2012, **21., pp. 71-75.**
Impact Factor: 0,129

Conference lectures

1. Nagy D., Béni Á., Karosi R., Fawzi ES., Posta J.
Krómspeciációs módszerek kidolgozása és alkalmazása környezeti mintákra,
XXX. Kémiai Előadói Napok, 2007. október 29-31.,Szeged, Hungary, p. 85

2. Nagy D., Fawzi M.E., Kapitány S., Posta J.
Krómspeciációs módszerek kidolgozása és alkalmazása környezeti mintákra
51. Magyar Spektrokémiai Vándorgyűlés, 2008, Nyíregyháza, Hungary, p. 116

3. D. Nagy, F. M. Elsaih, S. Kapitány, E. Orosz, J. Posta
Separation/preconcentration of Cr(VI) with continuous extraction device and single drop microextraction and determination by FAAS and GFAAS methods,
Colloquium Spectroscopicum Internationale XXXVI, 30 Augustus – 3 September, 2009, Budapest, Hungary

4. D. Nagy, I. Hegedűs, F. M. El Saih, J. Posta
Indirect determination of sulphur dioxid, sulphuric acid and phosphoric acid in natural samples by FAAS,
International Conference on Natural and Artifical Ecosystems in the Somes-Cris-Mures-Tisa River Basin, 2010 május, Arad, Romania

5. Nagy D., Falussy Cs., Béni Á., Nagy Gy., Balogh A., Nagy T., Posta J.
Nagy hőmérsékleten lejátszódó folyamatok követése termikus és spektroszkópiai módszerekkel
53. Magyar Spektrokémiai Vándorgyűlés és Vegyészkonferencia, 2010 jún. 30.- júl. 2, Hajdúszoboszló, Hungary

6. D. Nagy, I. Hegedűs, S. Kapitány, F. M. ElSaih, J. Posta:
Indirect determination of sulphur dioxid, sulphuric acid and phosphoric acid in natural samples by FAAS
Colloquium Spectroscopicum Internationale XXXVII, August 28 – September 2, 2011, Buzios, Rio de Janerio, Brazil, OP41

7. D. Nagy, I. Hegedűs, F. M. El Saih, S. Kapitány, J. Posta:
A new technique for the indirect determination of sulphur dioxid, sulphuric acid and phosphoric acid in natural samples with FAAS
XIV Hungarian – Italian Symposium on Spectrochemistry and 54 Annual Meeting of Hungarian Spectroscopists, 5 - 7 October, 2011, Sümeg, Hungary p. 29

8. Nagy D., Falussy Cs., Nagy T.,Posta J.
Nagy hőmérsékleten lejátszódó termikus folyamatok követése spektroszkópiai módszerekkel,
Mobilitás és környezet: járműipar, energetika és környezetvédelem konferencia és 55. Magyar Spektrokémiai Vándorgyűlés, 2012. július 9 - 11., Veszprém, Hungary

Conference posters

1. Nagy D., Béni Á., Posta J.
Króm(VI) extrakciós elválasztása, dúsítása aliquat-336 segítségével és meghatározása GFAAS módszerrel,
Centenáriumi Vegyészkonferencia, 2007 máj. 29. - jún. 1., Sopron, Hungary, p. 240

2. D. Nagy, F. M. Elsaih, S. Kapitány, A. Béni, E. Orosz, J. Posta
Separation/preconcentration of Cr(VI) with continuous extraction device, single drop microextraction and determination by FAAS and GFAAS methods,
ESAS 2010, 5 - 8 Sept. 2010, Wroclav, Poland

J. Posta, L. Karaffa, É. Fekete, E. Baranyai, D. Nagy
Headspace SPME method for the detection of trichloroethylene with GC-MS after the treatment with halogenated hydrocarbon consuming bacterium culture
Colloquium Spectroscopicum Internationale XXXVII, Buzios, Rio de Janerio, Brazil, August 28 – September 2, 2011, FR28