AGH UNIVERSITY OF SCIENCE AND TECHNOLOGY

Ion Time of Flight Spectrometer for Multi-Photoionization Studies

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Supervised by

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Acknowledgments

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Abstract

This paper present the work of Piotr Konieczny during The DESY Summer Student Programme 2010 in the group of beam line P04 at the PETRA III source. The aim of this project was to prepare an ion spectrometer which was optimized for Multi- Photoionization Studies of gases. This report describes all the stages from simulation up to result of experiment made between 14.08.2010 and 1.09.2010 at Doris III the BW3 beam line. The aim of this experiment was to measure with high resolution the double photoionization threshold of Helium. Also measurements of Xenon and Nitrogen was obtained.

Introduction

Multi-ionization coincidence measurements of atoms and molecules are interesting field for atomic experimental physics. Preparing a setup for this measurements is the aim of Sasha's Deinert a PhD student in the group of Jens Viefhaus (P04 at Petra III/DESY). The setup has two main parts. First one is an Time-of-Flight ion spectrometer (iTOF) and the second one is a magnetic bottle Time-of-Flight electron spectrometer (eTOF). Both parts are adapted for synchrotron radiation light source to study multi-ionization processes. A simple scheme of a similar setup from Egil Andersson [1] presents Figure 1 below.

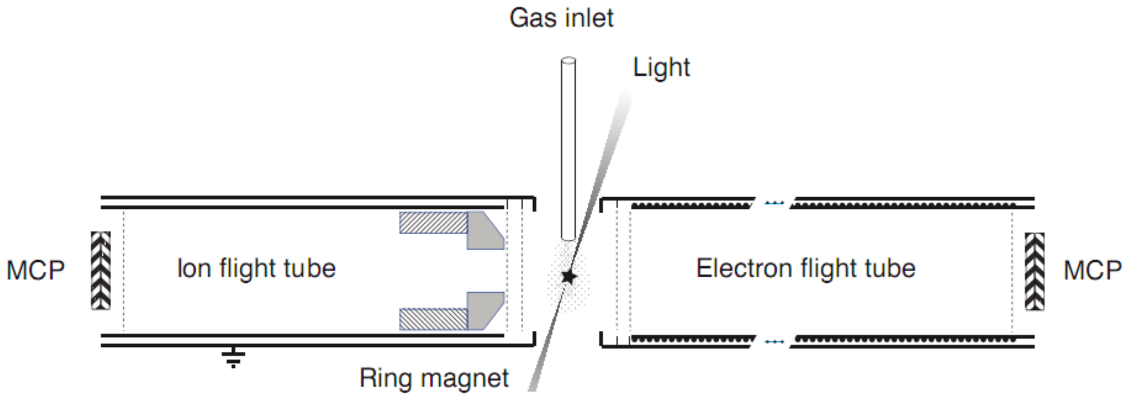

Figure 1. The scheme of electron-ion coincidence setup (MCP – multi channel plate) [1].

The operation of the set up starts at the point where gas from the gas inlet is ionized by the light. Then the electron are separated to the eTOF and ions to the iTOF, which allow to detect them in coincidence.

The target of summer student task was to prepare the iTof part. The work started with simulations, through manufacturing ion spectrometer detector, building the ready to use setup and testing the iTOF at the light source DORIS III at beam line BW3.

Simulations

The ion Time-of-Flight spectrometer which was used in this work is presented in Figure 2. The diameter of all elements of spectrometer was set as constant, simulations were performed to figure out the proper dimensions and voltages.

The purpose was to enable the measurement of multi-ionization processes in gases with synchrotron radiation light with decreasing the length of detector because of the time characteristics of DORIS III light source. The simulations was divided in two parts:

- Simulations using SIMION 8.0.4 software,
- Simulations using program of PhD Student Sascha Deinert written in python.

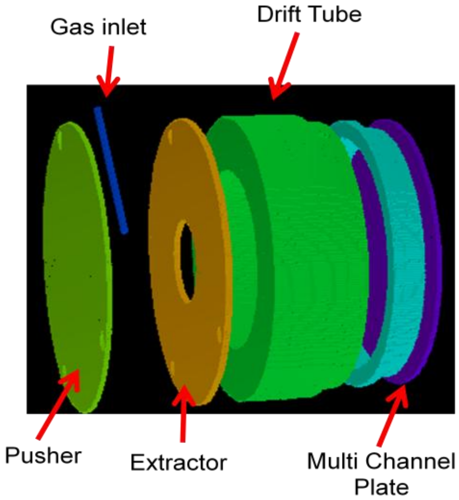

Figure 2. Picture of iTOF spectrometer detector.

The simulations was started using SIMION software. There were 8 typical ions chosen for calibrations: H^+, He^+ , He^{+2}, N_2^+ , N^+ , Ne^+ , Ne^{+2} , H_2O^+. The length of the drift tube was the first parameter to check. The range of simulated length was from 10 mm to 40 mm. Two models was chosen, 10 mm and 15 mm. The next step was to get the proper distances between elements and optimized voltages. Also different sizes of holes and grids were tested. The best candidates from first part were then verified with the program of Sascha Deinert. Beside the 8 light particles tested in the first part also two isotopes of Xenon (132 and 131 atomic mass unit) were used. A spectrum with best settings from this program is presented below in Figure 3.

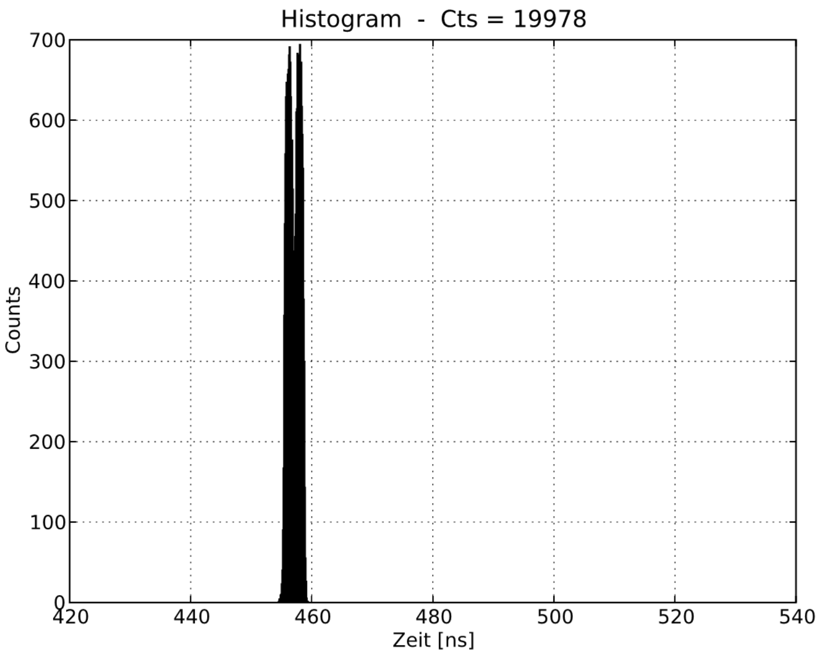

Figure 3. The spectrum of two Xenon two isotopes from simulations using python program (drift tube 10 mm, voltage on: pusher +2000V, extractor -2000V, drift tube -2900V, front grid MCP -3000V, x axis time in ns, y axis counts).

Analyzing Figure 3, both isotopes are separated and can be recognized. Although the ion spectrometer was designed for light elements, the simulation shows that even at least some main isotopes of Xenon can be resolved.

Experimental setup

The basic idea behind a time-of-flight ion spectrometer is to measure the velocity of the ions. This is achieved by placing a detector at a known distance and measuring the ions time of travel between the locations where they are created (in this case, but this can define in a different way) and detected. In this case the interaction region was in the middle between pusher and extractor, next to end of gas inlet (Figure 4). The light goes through this region ionizing the gas from gas inlet. A positive potential on the pusher and a negative potential on the extractor create an electric field that accelerates ions to the drift tube and then to the MCP detector.

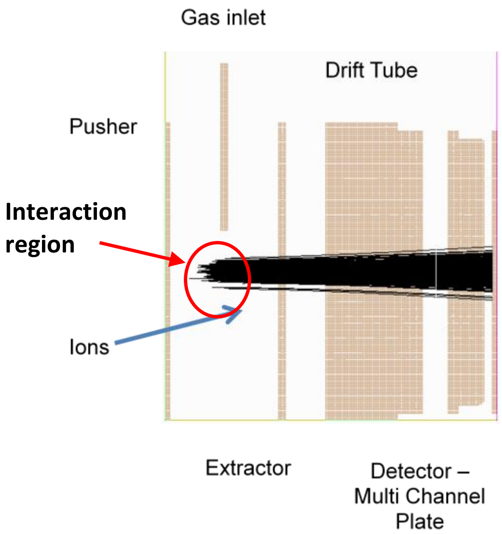

Figure 4. Scheme of ion spectrometer. Screenshot from simulation in SIMION software.

The ion spectrometer based on the simulations results was prepared in P04 group. The parts were prepared for use in ultrahigh vacuum with special care for those elements which are exposed to high voltage. The assembled detector is presented in Figure 5.

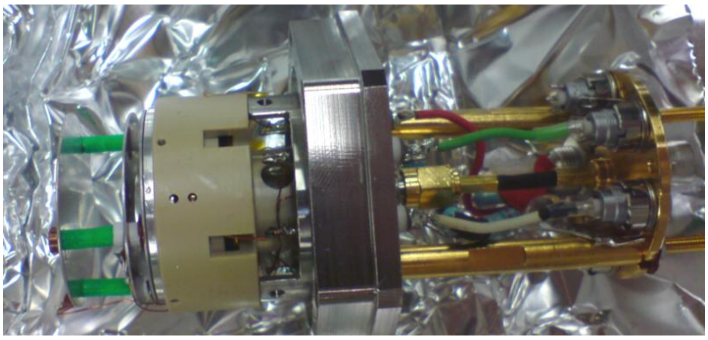

Figure 5. A photo of prepared ion detector.

After manufacturing the detector it was implemented into the vacuum system presented below in Figure 6. The setup contains a quadrupole mass spectrometer for measuring residual gases and to make comparison between iTOF and quadrupole spectrometer.

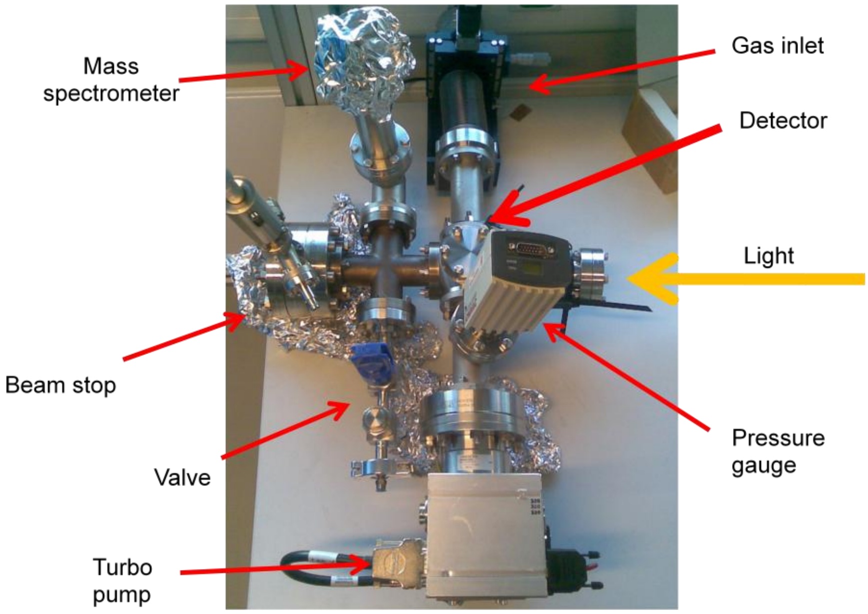

Figure 6. A photo of experimental setup for iTOF.

The setup was installed on beam line BW3 at Doris. The characteristic of BW3 beam line [2]:

- Two undulators, 4 m length, number of periods N = 21 and 44,
- 20 -1500 eV photon energy region,
- Spot size at sample: 100 μm vertical and 200 μm horizontal,
- Typical flux at sample $3x10^{12}$ photons/s in 0.1% bandwidth at 500 eV for 100 mA electron ring current.

Experiment

During the beam time numerous measurements were made to achieve the best quality of spectra. Light alignment, optimization of the voltages of all elements, discrimination threshold, pressure of sample gases were be formed the parameters which were optimized. All the data from the ion spectrometer were calculated and evaluated using program in python which was written specially for this beam time. Data from experiments were in ASCII format with two columns, first the index and second one the number of counts. In one file there are 10 spectra (from 10 bunches) one after another one, the program written in python puts all spectra on each after. The output is one spectrum with counts from all 10 spectra.

The comparison of spectra from quadrupole and iTOF spectrometer was the first test of new setup. Figure 7 and 8 shows both spectra.

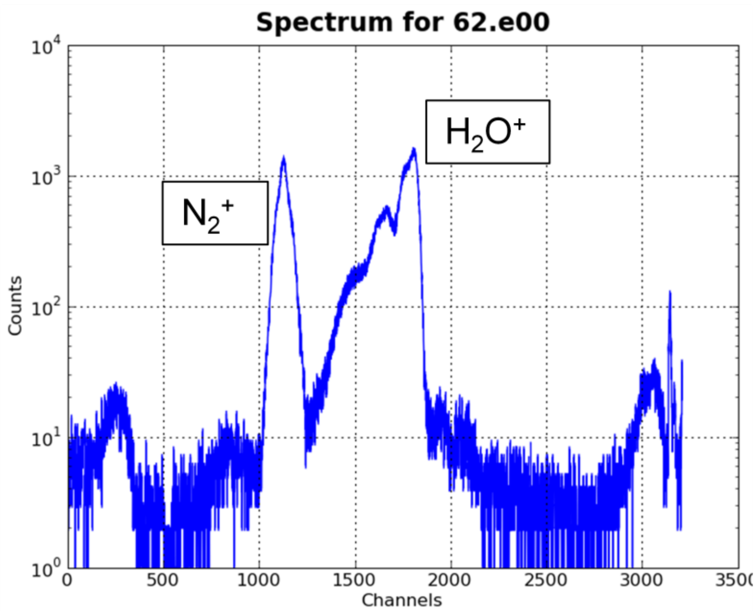

Figure 7. Spectrum of residual gases measured by iTOF (y axis is a logarytmic scale of count,on x axis are channels which can be identified by time of flight witout calibration).

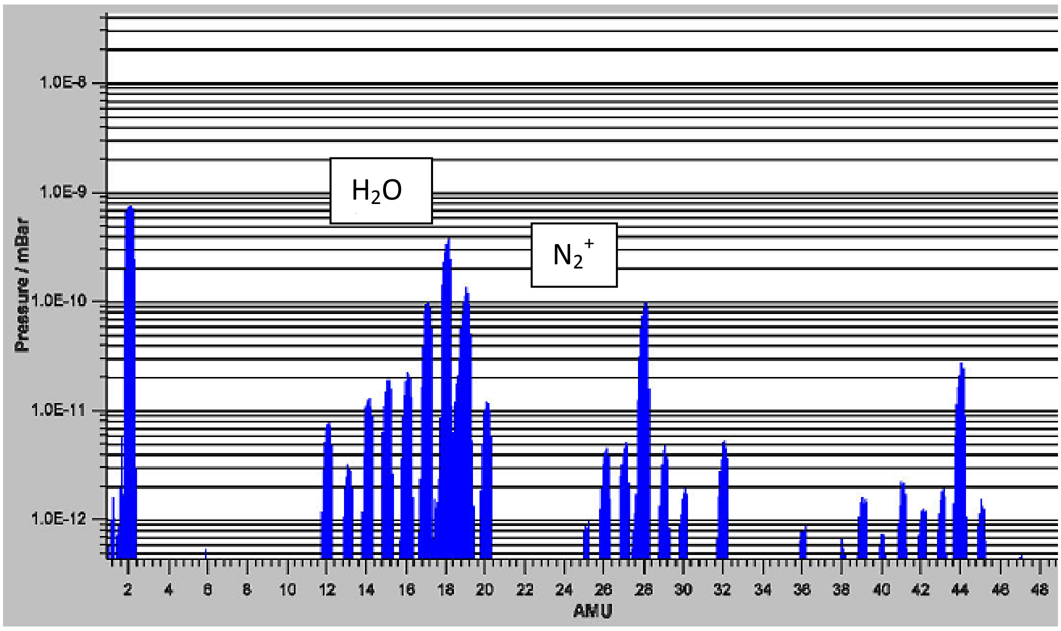

Figure 8. Spectrum of residual gases from quadrupole spectrometer (y axis is a logarithmic scale of partial pressure in mBar, x axis is in atomic mass unit).

Comparing spectra from figure 7 and 8 it is possible to recognize in figure 7 peak of H_2O^+ and N_2^+. Although N_2^+ is heavier than H_2O^+ the peak of N_2^+ is before H_2O^+. The reason this is the time characteristic of DORIS light with 5 bunches heaving a period of 192 ns (the interval before 5th bunche is 196 ns). The N_2^+ ion is too heavy and its time of flight is longer than 192 ns so the position of N_2^+ will be: {time of flight N_2^+}-192 ns (in this case).

Another test for the iTOF was the measurement of Xenon isotopes. Figure 9 shows the naturally occurring isotopes of Xenon [3]. The same isotopes were simulated using the program of Sascha Deinert (spectrum in figure 10). The final step was to compare this with the measurement using iTOF (figure 11).

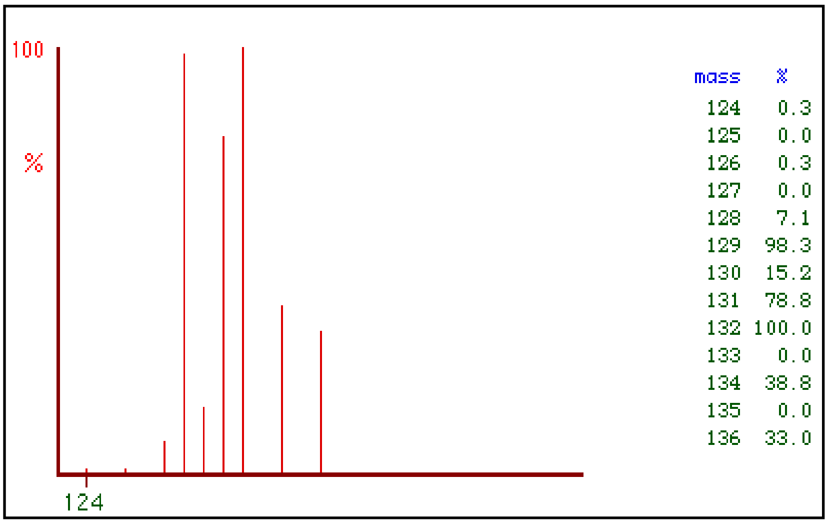

Figure 9. A graph of Xenon isotopes. The y axis present the percentage of occurrence. The most intense ion is set to 100% (y axis occurrence, x axis mass) [3].

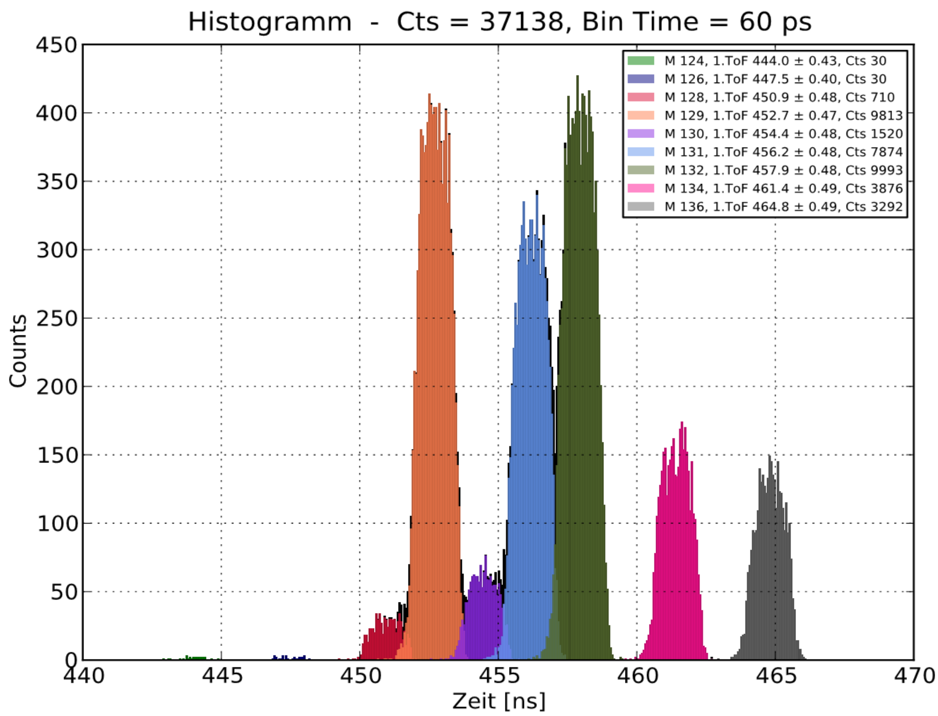

Figure 10. Simulated spectrum of Xenon isotopes (x axis time in ns, y axis counts).

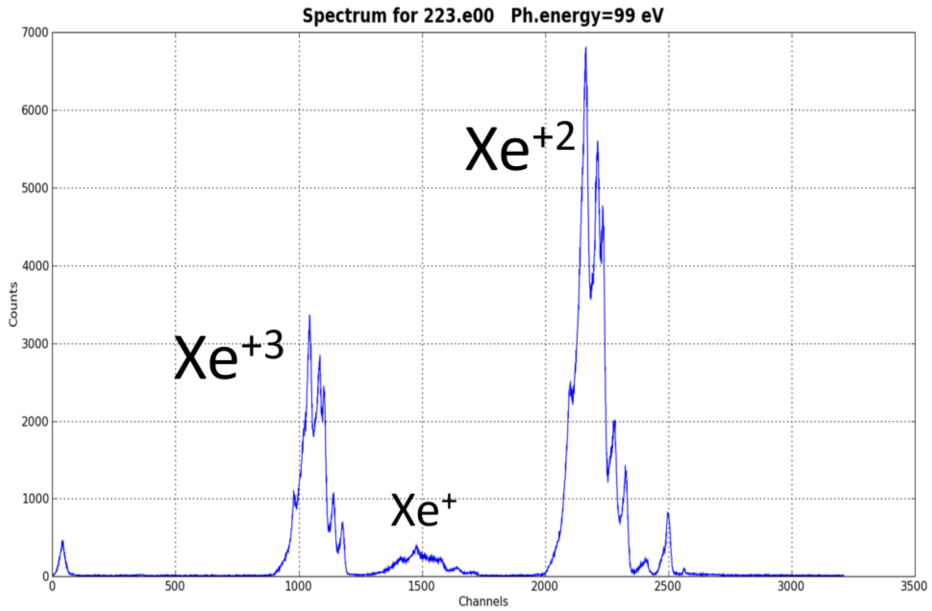

Figure 11. Spectrum of Xenon isotopes (y axis count,on x axis channels which can be identified by time of flight).

The simulations shows that at least 5 peaks of Xenon isotopes can by identified and its occurrence is similar to the source data from [3]. The measurement shows that 4 isotopes can be distinguished, but the height of peaks is not the same as in literature. The reason of that can be that some of the peaks overlap. In figure 11 the Xe^{+} elements seem to be faster than the Xe^{2+}. The m/q (mass per charge) Xe^{+} is bigger than Xe^{+2} and Xe^{+3} but due to the short time period of the DORIS SR light pulses, the Xe^{+} ions travel longer than this period. This is the same effect as in N_2^{+} in figure 7.

During the beam time also gases of Helium and Nitrogen were measured.

Summary

During the Summer Student Programme 2010 in DESY I have made all steps necessary for the preparation of the ion Time-of-Flight experiment. The first step were the simulation with SIMION 8.0 software and a python script. Furthermore I was helping with assembling the ion spectrometer and building the experimental setup. I attended the whole beam time at BW3 from 19.08.2010 to 1.09.2010. I wrote a program in python for developing experimental data and I evaluated this data. Furthermore I was participating in activities of group P04 at Petra.

The ion spectrometer fulfilled the desired task. However the experiment shows that many things can be further improved. The collected spectra give evidence that this setup can be used for multi-photoionization study in the future.

References

1. Egil Andersson *Multi-Electron Coincidence Studies of Atoms and Molecules* – Acta Universitatis Upsaliensis, Uppsala (2010)

2. http://doris.desy.de/

3. http://www.webelements.com/