The use of Scientific analyses as a Supporting component in the Auction House: in an example of EDXRF study on Chinese Artefacts

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Contents

Appendix 1

Bertolami Fine Art Internship Itinerary

Appendix 2

Spectra of EDXRF on Sample 77
Spectra of EDXRF on Sample 82
Spectra of EDXRF on Sample 83
Spectra of EDXRF on Sample 85A
Spectra of EDXRF on Sample 85B
Spectra of EDXRF on Sample 100B
Spectra of EDXRF on Sample 149
Spectra of EDXRF on Sample 295
Spectra of EDXRF on Sample 296

Abstract

The global art market has always faced the problem of being flooded with frauds and forgeries. And the auction houses are looking for alternative ways to strengthen their expertise in distinguishing the real artefact from the fake ones. This paper observed the adaptation of various scientific techniques to be the solution.

The auction houses are seeking support from technical and scientific examinations in order to overcome the questions on authenticity and attribution. It was believed that physical evidence obtained through scientific methods would be useful in settling disputes.

In particular, this paper addressed an example of scientific analysis, Energy Dispersive X-ray Fluorescence (EDXRF) that was used in an auction house in Rome. The EDXRF is a non-destructive and efficient instrument, providing chemical composition that offer objective insights of the component of the sample.

Results from pigments in samples of 18^{th} to 20^{th} century Chinese porcelain and wallpaper painting shown the colour were generated by metal oxides, yet because of the high lead detected from the samples and limitations of the equipment, it is only possible to have a general on the metal colouring agent and unable to name the specific pigment.

The results generated from the EDXRF provided investigative leads to help with the identification of the dating, combined with the documented historical provenance of the work, it enhanced the value of the artefact.

Portable EDXRF might be a worthful start to be an in-house scientific assistant. It is using scientific analysis to determine whether the physical substance of the piece complies with its attribution and provenance. Therefore, it is beneficial to the auction house to consider taking a scientific approach in the attribution process of an artefact.

Acknowledgements

There is an old Chinese saying: "Better to travel ten thousand miles than to read ten thousand books". Putting it in my experience, I would say this Erasmus Master programme ARCHMAT have fulfilled both successfully.
Being able to see such vivid sceneries with my own eyes and living in them which I have only read or heard of before, and to connect knowledge with the historical remains directly, gave me thrills. Studying and visiting at the same time have broaden my horizon of the world and of different culture, the course enlightened my thoughts and I greatly benefited from them.

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1. Introduction

"Being able to access numerous aspects by a scientific approach increases the fascination beyond the borders of pure art studies and brings together two fields of human activity that inspires and deepens the understanding of both fields: science and art."[1] – Richard R. Ernest

1.1 Science and the Art Market

Throughout the centuries, art and science go hand in hand to shape the manner in which humans interact and understand the world ard us. Oftentimes, scientific breakthroughs are made possible with a great deal of creativity, and art could be an expression of prominent scientific knowledge. For instance, science is involved in mixing paint in the correct proportions, or creating perspective in a drawing.

Therefore, knowing the nature of a work of art through scientific analysis would provide an additional support in the identification of the previously hidden connections and processes.

In the past, museum curators and auction house owners would seek help from expert connoisseurs, or art historians, for determination of attribution for a piece of art. In recent years, with the forgery scandals rampant, and the perennial method of the process of art attribution was being criticised, the Art Market is seeking for an alternate approach to add to their palette. The auction houses started to invest into science for more support, in the believe that when the cooperation of varies scientific experts combining with traditional connoisseurship, the scientific methods could support and eliminate the doubts on authenticity.

Addressing the questions of authenticity through complementary contributions of appreciation and fundamental research could deliver a strong statement on the importance of art history and the value of science being use as an supplement of the connoisseur's evaluation.

The longtime issue of forgery, was not only disturbing the Art Market, it affected the museum collections as well. Art scandals took up the headlines and caused economic consequences. The fraud and forgeries have also distorted the history of art and undermined the integrity of auction houses and museums:

A German art forger Wolfgang Beltracchi was confessed of a $100 million international art scam in 2010, in forging hundreds of contemporary paintings attributed to famous artists including Heinrich Campendonk, Max Ernst, and Max Pechstein, then selling through auctions. His forgeries entered museums and galleries all over the world, and many have not been uncovered.[2]

The Knoedler Gallery in New York, one of the oldest and respected art gallery in America, was closed in 2011 amid lawsuits for fraudulent, accused of selling millions of dollars of paintings in the past 15 years from the gallery and its president Ann

Freedman, were forgeries.[3] The fakes were paintings of works claimed to be by some of the most valued artists of the 20th century, Willem de Konning, Jackson Pollock and Mark Rothko, among others, composed this $80 million art fraud. All the fakes were reported to be painted by a Chinese immigrant in his garage in Queens, and referred to Knoedler by an art dealer Glafira Rosales.[4]
In these two cases, the forgeries with fabricated provenance have succeeded in deceiving the connoisseurs' eyes to enter the auction houses. In both situation the paintings were discovered, with the support of science, containing "historically inaccurate"[5] elements, which were not possible to be created at that time.

Due to the continuous of large-scale forgery cases, auction houses have to regain their reputation and collector's recognition as a reliable institution in the expanding art market, in this respect they have to work closely with modern science for success.
In December 2016, one of the top international auction brand Sotheby's, acquired Orion Analytical – an American research lab founded by James Martin, who specialised in forensics and the scientific detection of forgeries – and established the Department of Scientific Research, becoming the first auctioneer to own an in-house conservation and scientific analysis unit. The objective was to increase confidence and strengthen its reputation among sellers and buyers, also to better protect the company from expensive warranty claims. With this move, the company expect it to be a line of fortification against the inflating amount of counterfeit into the market.[6] The team's findings on a broad variety of artworks have proven to be crucial in supporting the experts confirm authorships, enhancing the understanding of the work's condition offered, and sometimes helped to solve disputes.[7]
Meanwhile the other leading international auction house Christie's, remain its close connections with vary independent laboratories that specialised in relevant genre and materials that offer unbiased judgements to settle questions of authenticity and attribution.[8]

A decent authentication process requires the presence and comparison between connoisseurship, scientific technique, and provenance. The mismatch between the painting period and provenance, the real age of its constituents is the main focus of scientific investigation. While scientific analysis could not provide any elements distinguishing between two paintings of the same era with very similar aesthetic features and palette, the differences of brush strokes and style could be found by the eyes of the connoisseur. On the contrary, appropriate scientific technique is crucial to confirm the connoisseur's judgement on the work of art.[9]

Scientific examination adds another layer of assurance on the authenticity of the Art work. Although science is unable to confirm authorship, merely providing critical support and evidence, these information provide invaluable insight on the determination of authentication, by excluding the unusual materials or techniques that are inconsistent with the work of artist.[10]

1.1.1 Defining the Value of Art through Science

A work of Art is characterised by a set of principles, including cultural, historical, artistic, which relates to its authenticity and identity, all of these factors lead into a form of number that formulate the specific price, indicating its economic-mercantile-market value.[11]

The provenance indicates if the work of art has exhibited in a prestigious collection or museum, or if it was mentioned in academic papers, these were terms of authenticity and high aesthetic quality, both are significant relevance to economic value.[12]

Now, science has brought about another definition on the value of the work of art. The application of appropriate diagnostic and analytical techniques would be essential to knowing the composition, construction, and condition of the work, which are factors influencing the value.

The provenance research by art historians and scientific analysis by scientists are both supporting the valuation of art, with attributions or the dating. The reports could fluctuate the value of the art, from attributed to an anonymous and found it belongs to a well-known artist, or the reverse.

It is more than common that a work of art was found fake or miss-attributed after scientific evaluation, “probably 98% (of paintings examined) are fake” [13] “people estimate that 20-50% of all works in the world are forgeries, misattributions, or unknown”[14], said by James Martin and Nica Gutman Rieppi respectively, both of whom are experts in the field of art analysis and research. It is without doubt the authenticity and reattribution would affect the value of the art.

Scientific investigation and conservation of the work can confirm its attribution and may therefore increase or decrease its value and thence the corresponding price. Scientific research of art is not a single means of determining its economic and artistic value, it too often have found discoveries that provide new knowledge on artists and their working techniques.

1.2 Scientific Analyses on Arts

Research on the physical properties and chemical composition of the work of arts are supportive and progressively used to assign its specific historical environment, to determine the authenticity of claimed provenance or to explore the creation techniques.

The following are a few scientific techniques that can be performed for identifications: X-rays photography, Ultraviolet fluorescence imaging, and Infrared reflectography could reveal refinement of underdrawing and artist brushstrokes of the painting.

X-ray fluorescence spectroscopy is used to detect chemical elements to identify inorganic pigments. Raman spectroscopy and Fourier transform infrared spectroscopy (FTIR) can also for pigments investigation, they can confirm and help detection on historically inaccurate paint pigments.

Bomb curve analysis is for dating contemporary artworks that were created in the past 50 years, due to the frequent nuclear weapon tests in the 1950s to 60s, there was a climax in radiation in the atmosphere, in which quantifying the amount of radiation present in the artwork could give a more precise date.

The choice of appropriate scientific tool and to analysis all the layers in the work of art is significance, the scientist should be conscious that the material present on the surface may not be suspicious and lead to erroneous conclusions.

The increasingly advanced technologies have allowed the scientists to hold and conduct investigations more easily, with more convenient equipment and less or even no samples required. Thus, the reduced analysis costs appear more appealing to the auction houses that seek assurance of the authenticity of the work of art.

The canvass of various approaches for detecting forgery and authenticity of the work of arts confirmed the critical role science plays as a supporting role in clarifying forgeries and validation, the close conjunction between art historians and scientists would have reached the unequivocal conclusion.

1.2.1 X-ray Fluorescence (XRF)

Nowadays, X-ray technology has evolved in great progress, and developed versatility on art analysis methods.

X-ray fluorescence spectrometry is able to determine the nature and composition of a inorganic sample, it is based on the principle of detecting the characteristic “secondary” (fluorescent) radiation emitted from the excited inner electron shells of the atoms by a high-energy X-rays. The sample is excited with external primary X-rays, during this processes, electrons from the inner shell are knocked out, and the electrons from the outer shell will fall and fill the space emitting fluorescent radiation, which is characterised by the energy distribution of the particular material. The fluorescent radiation is evaluated by a detector.[15]

Through the detector, the detected radiations are shown as a spectra of peaks of different heights with different energies through the connection of software. The energy corresponds to its source chemical element, and the height of the peak is related to the abundance of the element in the sample.
XRF is a simple method for the qualitative and quantitative analysis of chemical elements, however, it is predominantly a surface analysis technique and difficult to measure light elements, requiring a combined use of complementary instrumentation in archaeomaterial investigations.
Because of XRF's non-destructive nature, of minimal or no sample preparation required, it is widely applied in elemental and chemical analysis of cultural heritage, for a first and fast characterisation on materials of metals, glass, ceramics, paintings and murals.[16] To investigate elemental impurities to determine the source or identification of the material in the same work of art because of restoration or partly unoriginal with high accuracy and precision.[17]

1.2.2 The Technique Ideal for the Art Market

XRF analysis could generate a rapid yet informative result through a full identification of chemical elements in the work of art. The raw materials and formulas used in different production periods could be detected by XRF classified with their unique chemical compositions, which enable to support answers on authenticity, province, date and restoration.[18]

Portable XRF spectrometers are now commonly used in museums and galleries, allowing the elemental investigation and characteristic of a given work of art to be determined in-situ and non-destructively. It is particularly favourable for analysing complete objects, when sampling is not considered because of the integrity of the item, such as porcelain.[19]
It could be tested on various materials, such as paintings, silverwares, and glass, to indicate whether its composition were identical with the painter's resource that may unravel the artist's technique, suggesting the date and the authenticity of the work simultaneously. The results could also give an idea on restorations if needed.
Being a portable instrument, portable XRF can be obtained with a lower affordable cost, considering its non-invasive feature and ability to conduct high precision and reproducibility analysis on most of the artefacts within seconds, it is presented in a good value for an auction house.

1.3 Practical Practice of Science in an Auction House

In the course of this dissertation, I have participated in working as a assistant in an auction house in Rome. During the two months of internship, I took part in the full process of organising an auction. Furthermore, I have selected 8 artworks (7 chinaware and 1 Chinese wallpaper-painting panel) which were offered for auction, and investigated with a portable EDXRF.
The details on the samples and results will be introduced in the later chapters.

In addition, for a broader range of experience, I have also attended the portable EDXRF examination of silverwares from China and Europe for the detection of the percentage of silver employed in the artefacts. The composition result would affect the estimation of the value, the more purity of the silverware higher the price.
The silver accessories from Liao Hmong China, were found to be an alloy of copper (Cu), nickel (Ni), and zinc (Zn), nearly no sign of silver (Ag) was shown. From the Europe antique silver ship models, on the contrary, high peaks of silver (Ag) proposed the models were production of silver.
By the use of portable EDXRF analysis, the composition of the silverwares can be known in a short period of time. In this matter, the accessories from Liao Hmong instead of made of silver are an alloy, and the European ship models are of silver. Combining this result with the information from the owner, the auction house can have a comprehensive consideration on the consignation of the work of arts.
This have gave another example of science application in an auction house, clarifying the composition of the artefacts can eliminate the possibility of consigning forgeries and act as a proof for both the auction house and collectors.

2. Internship at Bertolami Fine Art

Bertolami Fine Art was established in 2011, a newly developing auction house specialising in the sale of ancient coins and medals. The company is located in the centre of Rome, and have branches in London (United Kingdom) and Munich (Germany), Bertolami Fine Art is spreading its sales within Europe and Internationally. It also continued to expand its scale, and to date, Bertolami Fine Art have founded several new, specialised department. They are the departments of Archaeology, Modern and Contemporary Art, Asian and Tribal Art, and more, covering a wide range of expertise.[20]

I was especially interested in the logistic of the actual workflow of organising an auction, and to participate in the scientific analysis on items which will be in the Asian and Tribal Arts Auction 64: "Eclectica - Arte Asiatica, Africana e Americana da Collezioni private Italiane (Eclectic - Asian, African and American art from Italian private Collections)". Furthermore, I was able to join Bertolami Fine Art for 2 months as an intern to assist in the preparation of the Auction 64, and to apply non-invasive analysis with portable Energy Dispersive X-ray Fluorescence (EDXRF) on selected samples from the collection.

Please refer to Appendix 1 for my internship itinerary.

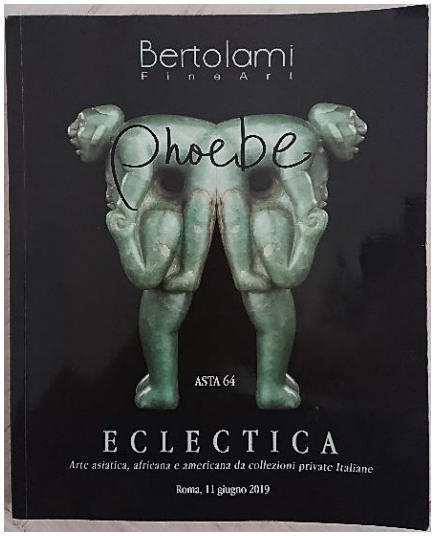


Figure 2.1 Catalogue Cover of Auction 64 (photo by author)

2.1 Organising an Auction

2.1.1 Collection from Clients

The project and theme of holding an auction is not fully determined by the auction house, instead it depended on the items and collections they have consigned from the clients. Clients would approach the auction house with item(s) or collection that they would like to sell, some were collected by the client themselves, and some were inherited from their family. All the items with common elements will be selected guardedly to form a subject of the whole for the next upcoming auction.

A clear and detailed provenance is always preferred. A thorough and validated provenance of the item can lower its possibility as forgery and may have a better estimation in price. However, as mentioned before, even the record of the provenance can also be counterfeit by forgers, consequently the art piece in this respect as well.

Through emails and meetings, the specialist from the auction house will conduct a careful inspection into the condition and value of the item, and to evaluate if the item is suitable for the auction house. If the specialist decided to consign the item, an estimation of the approximate price would be offered. In the event of the item

remaining unsold, advice would be given on the legal regulations and next possible action to take.
After the discussion on the price and other conditions, if the client agrees, then a contract will be signed and documented, and the item is consigned to the auction house and awaits for the appropriate auction.

2.1.2 Description and Photographs for Documentation

With the item in hand, the specialist will began an in-depth study on the item. Literature research would be conducted, in order to write a concise description and perhaps an essay. In general, no scientific analysis would be conducted on any item prior to sale.
In addition, a condition report will be composed on the condition of each of the items. The specialist evaluates the conditions in an appropriate manner to the estimated value of the item and the theme of the auction which included it. The item will then be passed to a professional photographer for photographs. The photographs should allow the clients be able to observe the full appearance and some important details, for example the production mark on the bottom of Chinese ceramics.

If the item is of coral and/or ivory, these would require a certificate issued from CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) before putting on sale. CITES is a global intergovernmental agreement, aiming to ensure the international trade of wild animal and plant specimens do not threaten their survival. It works through putting in controls on international trading in specimens of selected species, to protect them from overexploitation.[21] All antiques that are (partly) made up of specimens of wild animals and/or plants covered by CITES are necessary to be authorised through the licensing system for approval to trade, so as to avoid the loss of Nature.

When all the descriptions, photographs, and documents were ready, the items that were chosen to be in the auction will be assigned a lot number (lotti) for the auction, this lot number will represent the specific item in the auction.
In Auction 64 that I have took part in, has a total of 424 lots, sorted according to the collection of the original owner. Consisting of items from East Asia (China, Tibet, Japan, and Korea), South-East Asia (Thailand, India, Indonesia, etc.), Africa and Mexico. The Asia collection contained a variety of Arts, from paintings, sculptures to ceramics; the African and Mexican Tribal Arts are masks and sculptures made of wood and jade.

2.1.3 Catalogue: Printed VS Digital

Once the entries of the auction are closed, the graphic designer will undertake the process of cataloguing. The prepared descriptions and photographs of the items, the catalogue essays, estimates of the prices, information about relevant taxes, terms and condition of the auction house, will be featured respectively in the printed catalogue and on the website.

Figure 2.2 Content of Printed Catalogue of Auction 64
(photo by author)

The descriptions of the items are only references, it does not fully indicate the condition of the item that it is without flaws or imperfections.

The catalogue essay was written by experts and provided the historical sources of information that extended the numbers marked for sale. It is an opportunity to learn an item in a broader context, to understand the artist or creator, and the value of the item. The additional research identifies the theme or determines the date of work, it can take some careful explanations neutrally. This way of phrasing can allow the readers to have enough information to make an informed decision. For some private auctions, the catalogues could be more into presented in an academic format.[22]

After the final proofread, the printed catalogues will be mailed to clients by the publisher, it is an important and the most direct way to reach the clients.

However, in the age of fast-paced lifestyle, the demand for information delivery have changed. People prefer reading on their mobile phones than holding a catalogue. In an age of rapid information sharing, newsletter or subscription via email, glamorous photos, innovative short videos and stories on media are becoming the mainstream. Through interactions on social media, it is more possible to reach out to more potential clients and offer opportunities to advertise every categories.

In the view of current trend, auction houses are increasing the investment in online platforms, to provide better service to interested parties.
Despite the fact that the numbers of printed catalogue has declined in the recent years when internet and mobile phones were getting more common – 2007, Sotheby's held 310 auctions and printed 2.5 million catalogues; in 2017, were 334 and 1.1 million respectively.[23] The printed auction catalogue remains one of the most important way to promote the auction and as a sales channel. It is a hybrid of science and commercial, maintaining a balance of academic and marketing features.

2.1.4 Viewing

Pre-auction exhibition at the gallery are open to the public and free of charge, it opened circa a week before the auction and will last for 5 days, which varies depending on the different auctions and auction houses.

During viewing, every lot that is included in the auction will be on display, the clients have the occasion to observe and touch the items in a close distance.

While the catalogue and condition reports may not fully express the status of the item, all clients are recommended to inspect the items of interest at the exhibition. Specialists will be available at the viewing or by appointment to provide advice and condition reports.

If the client is abroad and was not able to attend the viewing, the person may request for more detailed photos and condition reports via emails.

Figure 2.3 Exhibition of Auction 64
(photo by author)

2.1.5 The Big Day

The auction is held after months of preparation. Bids can be placed in person during the auction, or through online live auction or telephone. During my internship of Auction 64 at Bertolami Fine Art, the auction was held on the 11th of June and divided into 2 sections. In the first round started in the morning at 11:00, bids of lot 1-195, and on the second at 15:30 on lot 196-424.

Particularly, in the category of Asia and Tribal Arts, the majority of clients were Asian and live overseas. They participated the in auction through the online live auction or via telephone. Clients were very active during the auction, and the event went expenditiously. Lots from East Asia (China, Japan, and Korea) gained the most attention, followed by ones from South-East Asia (Thailand, India, Indonesia, etc.). In contrast, Tribal Arts from Africa and Mexico received less interest.

There were moments where several buyers engaged in competitive bidding over a piece of work. Asian paintings, ceramics and jade wares were the lots having the final hammer price reached a double or more of the opening price: Lot 121 – an 18th-19th Century Chinese White Jade Carving with Two Mushrooms and an Insect have the last bid at 1,500EUR from 300EUR; another Lot 204 – a set of Five 19th century Indian Miniatures was sold for 3,600EUR with the starting price at 400EUR.

Figure 2.4 Auction 64 in progress
(photo by author)

2.1.6 Post-Auction

Sales do not end simplily after the auction, clients would have the chance to approach for the unsold items. They may ask again for the condition report and see the designated item in person.

The necessary documents for export and shipping of the sold items would be under preparation, it sometimes occur that the Italian Custom do not allow an item to be exported outside of Italy. After examination, the auction house can only refund and explain to the affected client.

For the auction houses, this can be an issue that is out of their control. Yet from the scientific and cultural view, this act helps to preserve the artworks within the country, as many valuables were sold to foreign private hands resulting the loss of open assess to the public.

2.2 The integratation of scientific analysis in the Auction house

Auction houses are places where fine artworks are presented and circulated, it contributes to knowledge in the sense of the compilation of the auction catalogues, and people of different expertise gathered to share and study the history and beauty of Art and Science.

For the duration of my internship at Bertolami Fine Art, I realised that common auction houses may not have the financial capability to send items for scientific analysis. Unlike the leading international auction houses that are able to own or cooperate frequently with laboratories, scientific analysis is over the budget of what minor auction houses could afford. Thence, these smaller auction houses relied on historical literature research on the items collection.

While there appeared to be a lack of usage of scientific analysis in auction houses, especially for the small-scaled ones, in the recent 10 years, with the expanding Art Market, the auction houses could be a potential market for scientific analysis of cultural heritage.

Nowadays, clients have growing concern on the authenticity of artworks, the demand of scientific reports as proof have raised. The scientific expertise complemented with specialists from the auction house across different collecting categories to examine the works of art.

As a matter of fact, there is a blooming number of new laboratories in the world specialising in cultural heritages. The industry tycoon Sotheby's have plan to expand and to establish the State-of-the-Art laboratory for scientific research in Hong Kong as a foothold in Asia, after New York headquarters and London, portable devices would also be available for world-wise.[24] This act implied the demand and importance of scientific evaluation inside an auction house. The introduction of science application on art reflects the trend of the world's major museums and auction houses providing better and more services to clients.

Minor auction houses may not be able to acquire an in-house laboratory, but if they could rent instruments according to their needs and examine the collections before consigning. The scientific measurement would be a solid support to the auction house, a means to reduce the chance of forgeries and enhancing their reputation.

The auction houses understand the significance of scientific analyses on Arts as a supporting factor in the determination of the attribution of the artefact. And the collaboration with art historians and scientists have encouraged the combination of the knowledge of art history and analysis of laboratories would have led to the "impactful determinations".[25]

3. Experimental Method

3.1 Portable Energy Dispersive X-Ray Fluorescence (EDXRF)

In this dissertation, portable EDXRF was applied to measure the inorganic pigment's chemical composition in samples of 7 Chinese porcelain and 1 Chinese wall painting panel.

The EDXRF spectra were recorded using an Amptek Mini-X X-ray tube with gold anode, operating at voltage of 37 kV and current of 15 mA, it is connected with an Amptek X-123SDD Complete X-Ray Spectrometer with Silicon Drift Detector (SDD) with high energy resolution 168 eV. The distance between sample and detector is about 1 cm, and 1 mm spot of analysis on the samples. The time of measurement on each spot was counted in seconds. This analysis was executed by the software equipped with the instrument.

The EDXRF spectra allowed the identification of elements that are essential to draw information on the pigments composing the colour palette of the porcelain and painting production at 18th to 20th century in China.

Portable Energy Dispersive X-ray fluorescence allow to perform a non-destructive, fast, multi-elemental technique in-situ, to analyse the surface layer for the determination of major and minor chemical composition of complete samples of various sizes and forms, providing reliable discriminate results. [26]

Figure 3.1 Setting up of portable EDXRF (photo by author)

4. Samples Background

Every sample can be found in the past Asian Art Auctions held by Bertolami Fine Art.
Since this dissertation is aiming to analysis the pigments' composition used in the Chinese porcelain, the samples selected were of famille verte, famille rose and canton style, which were characterised with the rich use of colours. Another Chinese wallpaper painting panel was also chosen.
All of the 8 samples are from the 18th to 20th century of Qing Dynasty (1644 – 1912) to the Republic of China (1912 – 1949).

4.1 Historical Background

4.1.1 The Export Trade with Europe during Modern Period

Since the 15th century, Europeans have begun to trade in China, tea, silk, and porcelain were the three most representing main product. Among them, Chinese porcelain was labelled as delicate and luxurious "white gold" and have fascinated the Europeans, the high prices of these rare and exotic Chinese porcelains could not cease the aspiration to own a collection of the noble class in Europe.

The Portuguese explorer Jorge Álvares were the first to reach Southern-China and operate commerce events in 1514,[27] imported the Jingdezhen's iconic blue-and-white porcelain wares together with other products to Europe. At this early stage, the fairly large group of various porcelain marked the success of Portuguese in establishing the far East-West trade route mechanism.[28]
Later the Dutch East India Company or Vereenigde Oost-Indische Compagnie (VOC) replaced the declining Portugal, followed the same trade model with a different commercial system,[29] and regarded porcelain as a more important merchandise. Between 1602 and 1682, the company have shipped around 30 million pieces of Chinese and Japanese export porcelain to the Europe market.[30] Being a precious property, Chinese export porcelains can be found in many Dutch still-life paintings from this period. The VOC have also requested for custom-made porcelain of Chinese patterns decorated on Western formed wares to satisfy the growing needs for European daily utility. Holland remains to be the ceramic trading centre meeting the European demand until the 19th century.[31]
When Qing (1644 – 1912) took over Ming Dynasty (1368 – 1644), maritime trade was resumed from the sea-ban and controlled by the Canton System, focusing all commercial activities at the southern port of Canton. Jingdezhen (the porcelain capital of China) was reconstructed and restarted the production of imperial and domestic wares,[32] a more diverse style and technique began to appear, blue-and-white porcelain was in its final phrase, and new palettes were developed.
The British East India Company (EIC) joined in the competition of the valuable Asian trade in the 17th century and dominated the Far East market. The English trade volume

exceeded the total amount of all other western counties, such as the French, Swedish, and Danish.[33] In the time of two centuries, Europe have imported hundreds of millions pieces of porcelain from China.[34]
During the 18th century, vast artistic activities were developed and many products were comissioned exclusively for exportation. Chinese craftsmen were known for their mastery in making porcelain, the workshops replicated models achieved from Europe, then altered and reproduced according to the tastes of Europeans.

Chinese porcelain have been promoted to the world, due to the centuries of trading. Foreign consumers have a strong interest in porcelain products and its manufacture. The transmission and mutual influence of designs and porcelain production showed the interactions among various culture.[35]
The Chinese porcelains are a projection of a form of cultural and economic communication the enables the exchange of realisation and experience of another culture.

4.2 Aesthetic of the Decoration

In China in the late 17th century during the Kangxi period (1661 – 1722), the demand on polychromatic porcelain from western customers was booming, to improve the efficiency of production, undecorated-blank porcelains made from Jingdezhen were shipped to Canton for post processing in painting popular elements or customised designs commissioned by foreign clients.[36] With the passage of time, the Canton workshops have evolved into its own unique genre.
Due to the active interaction and prosperous porcelain trade with the west, the western aesthetic preferences have penetrated into the style and method of the Chinese porcelain production. New designs and enamels were formed under the influence of the west, and were made especially for export to Europe, these export porcelain were characterised with rich colour and composition.
The formation of these new porcelain series was the new recognised as blending the new western designs and paintig techniques for traditional chinese porcelain. If coincided with the historical background of the 19th century China, where leading scholars and thinkers proposed the idea of “Chinese Learning as Substance, Western Learning for Application” which meant to appoarch Western skills while retaining core Chinese principles.

4.2.1 The Style of Famille Verte, Famille Rose and Canton

Famille Verte

In French meaning “the green family”, named from the variety shades of green in combinations with red, yellow, blue, and black, of the overglaze enamel applied during secondary firing decoration on porcelain. It was developed during 1680 – 1725 under the Kangxi era, and were made mostly for the internal market.[37]

Top quality famille verte porcelain are distinguished by the characteristic clean and translucent green enamels on the surface which mirror an iridescent when encountered with glaze.[38]

It has a charming Chinese perspective and illustrated a living daily scence, showing a diverse of flowers, animals, and landscapes, scenes with references inspired by Chinese block prints and novels of the period, featuring historical or religious characters.[39]

Famille Rose

A French name meaning “the pink family”, refers to the predominance of rose-red to pink coloured enamel, it has the name “yangcai” (foreign colours) in Chinese, as this new form used foreign materials and the technique of mixing pigments was “imported”. In 1685, the Jesuit missionaries brought the pigment Cassius purple to China which gave the colour to the creation of famille rose. It was first appeared at the Imperial Studio of porcelain porduction in Beijing. Famille rose wares were introduced and dominated during the Yongzheng reign (1723 – 1735), it was a very popular choice for exported porcelain.[40] The opaque white enamel was fired at a lower temperature and manifested a wider colour range, the flowery design was in reference to the emerging Rococo fashion in Europe. It was the perfect ware in the collections, all the styles of the theme and pattern were for the use of the noble class.[41]

The rise of famille rose is in part a result from the expansion and high demand in Chinese porcelain from the West, and also from fierce competition among private merchants.

Canton

In the 19th century between 1840 and 1880, the Canton launched a family of polychrome enamelled porcelain with various rose patterns merely for export, such as the Rose Medallion, in a standard palette of pink or green. These Canton porcelain were densely and diversified decorated with various graphics of flowers, birds, and figures, with the identical glittering golden-rim.[42]

The product was designed to cater for the taste of western market, and presented a fusion of the art and culture of both “exotic” art and culture.

4.2.2 The Form of Wallpaper-painting Panel

First appearing in the 17th century and popularised in the 18th century, "Chinoiserie" is the European interpretation and reimagination of Chinese and East Asian artistic style. It was considered to be trendy for castles or manor houses to have a "Chinese room", which led to the rich sheathing their home's walls with Chinese wallpaper.

Aside from internal decoration, the wallpaper were also mounted on panels to cover windows and boxes, or turned into sliding doors or screens.[43]

During this period, commercial trade between the West and China have reached the peak, commodity of various category entered the European market through the official and private trade of the English East India Company. The exotic wallpapers imported by the ship captains privately were very well recieved in England. However, the wallpapers were part of the minor merchandise of the trading sales, the wallpapers were not recorded in the official catalogue, hence there were very few literature documented on the subject.[44]

The two pieces of paper were jointed together to reach the required length. The common practice was to meticulously hand-drawn the outline by brush with black carbon ink before applying colour, printing is rare. The paintings depicted the Chinese ideology of mediating happiness and traditional religious beliefs, every composition gave indication to an implied meaning of harmony and blessings.[45]

Next, the painted wallpapers would then be mounted on stretched canvas on a wooden panel, backing papers were applied to enhance the strength of the panel, and to eliminating creases and cockling. The use of alum could adjust the size of the wallpaper, to harden the binder and glaze, and to render the pigments water resistant.[46]

The subject of the sampled wallpaper in this dissertation is a snapshot of the daily life and festival activities in China, presented with a backdrop of landscape mountainous view.

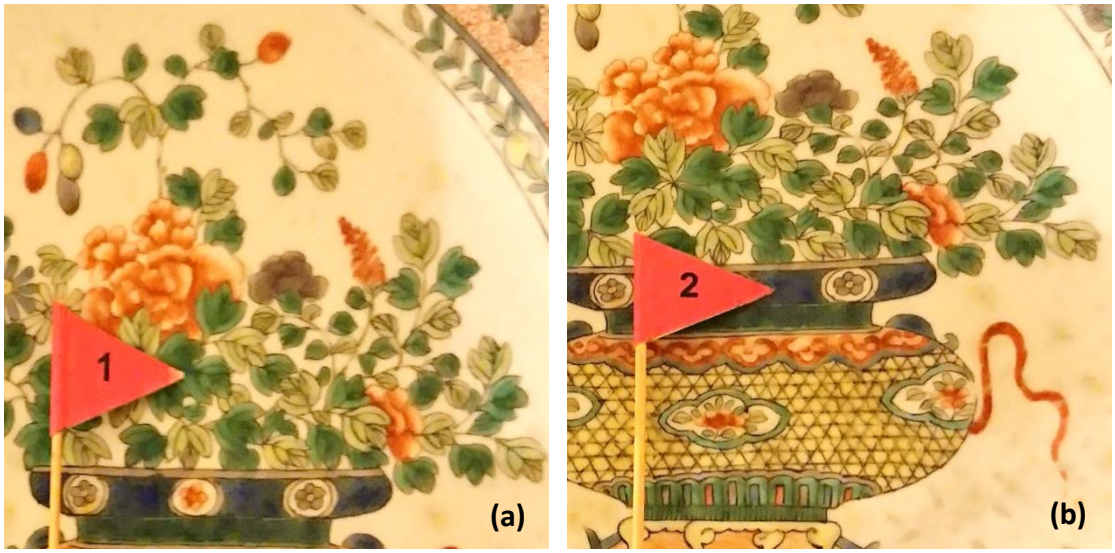
5. Samples Description and Result

5.1. Sample 77 – A Chinese Qing Dynasty "Famille Verte" Porcelain Dish

The Chinese "Famille Verte" Porcelain Dish is from Qing Dynasty (1644 – 1912), of 33.8cm diameter. In the centre drawn a basket of flowers placed on a pedestal, along the rim decorated with flower branches and cartouches with flowers on the ground in the inner circle. The dish shows signs of wear. Its provenance is a collection of an Italian diplomatic lived in Jakarta between 1958 and 1962.[47]

Figure 5.1 Facade & Bottom of Sample 77

5.1.1 EDXRF Results on Pigments of Sample 77



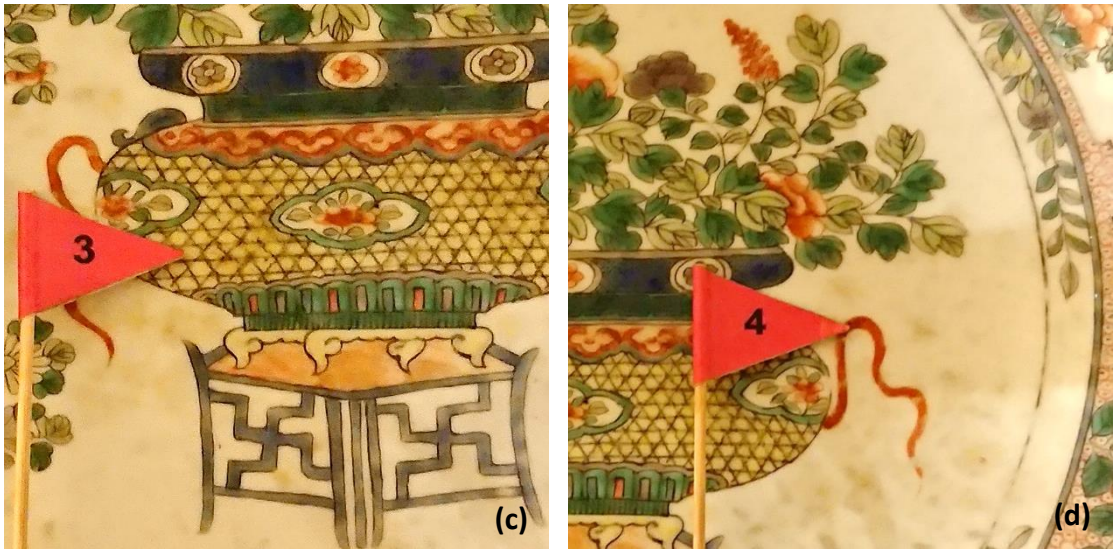


Figure 5.2 (a) Measure 1- green; (b) Measure 2- blue; (c) Measure 3- yellow; (d) Measure 4- red

Measure	Colour	Ca	Mn	Fe	Co	Cu	Zn	Hg	Pb	Sr	Accum Time
1	green	18	56	71	47	979	-	9	2356	6	35
2	blue	-	40	56	73	106	-	-	3615	-	24
3	yellow	-	-	88	-	-	163	-	5355	-	25
4	red	87	-	577	-	18	-	-	293	-	25

Table 1: The EDXRF data (net area) obtained for Sample 77

The spectra of Sample 77 showed the presence of high content of lead in all the four colour sampled of the plate, lead oxide was used as a flux to lower the melting point for glaze firing, and characterised of a rich lead-based overglaze.[48]

The green colour have a peak of copper in a lead-rich basis suggested to the use of malachite ($Cu_2CO_3(OH)_2$), in the 18th century China, copper and lead were mixed to obtain the colour green for decorations.[49]

The blue contains copper which may came from azurite ($Cu_3(CO_3)_2(OH)_2$), a greenish-blue pigment found in paintings since Song (960 – 1279)[50] and on blue-and-white porcelain of the Ming Dynasty (1368 – 1644).[51]

Yellow have high amount of lead, suggested the use of a lead-based yellow pigment, lead (II) antimonite ($Pb_2Sb_2O_7$) and lead-tin yellow type II ($PbSn_{1-x}Si_xO_3$) were introduced and commonly found in the colour palette of yellow enamels since Kangxi era (1661 – 1722) of Qing Dynasty,[52] in this measurement both antimony and tin were absent, therefore it is not possible to name the specific yellow pigment.

The red was identified as hematite (Fe_2O_3) from the peaks of iron, this red can give colours vary from bright red to dark brown according to the oxidation and reduction degree. Hematite has been used as pigment for the red decoration of Chinese artefacts from the 15th century.[53]

5.2 Sample 82 – A Chinese Second Half of the 19th Century "Famille Rose" Porcelain Baluster Vase

The Chinese "Famille Rose" Porcelain Baluster Vase is from Qing Dynasty (1644 – 1912) at around the second half of 19th century (1850 – 1900), of 44.3cm tall. The vase is in good condition.[54]

It did not provide with a provenance.

Figure 5.3 Facade & Back of Sample 82

5.2.1 EDXRF Results on Pigments of Sample 82

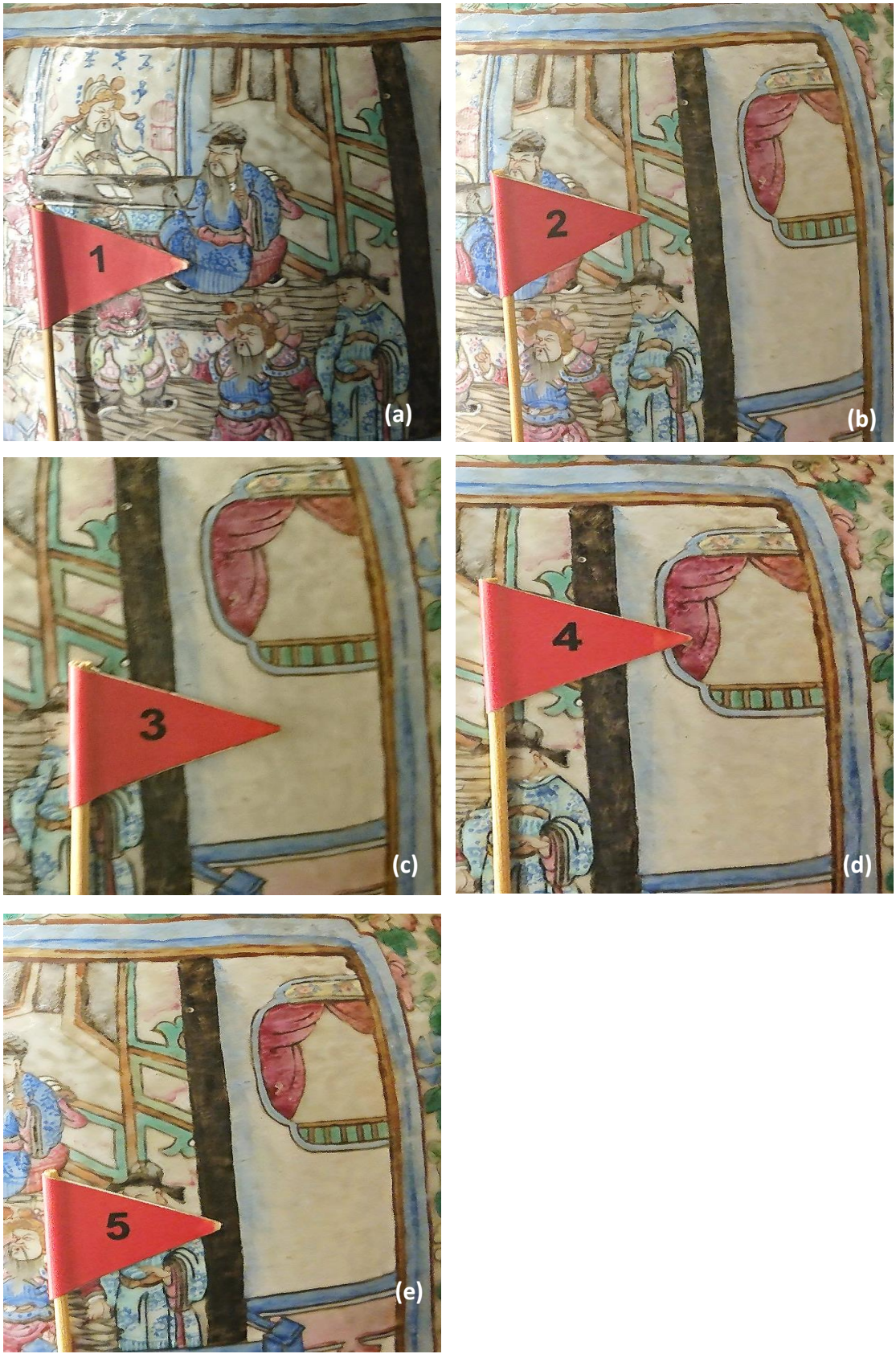


Figure 5.4 (a) Measure 1- blue; (b) Measure 2- green; (c) Measure 3- white; (d) Measure 4- pink; (e) Measure 5- black

Measure	Colour	S	Ca	Mn	Fe	Co	Cu	Zn	Pb	Accum Time
1	blue	-	49	121	435	145	210	-	5604	53
2	green	-	-	59	89	-	827	-	6641	33
3	white	-	-	-	105	-	67	-	6255	52
4	pink	34	-	-	101	-	72	-	5826	31
5	black	-	-	131	101	79	152	313	4924	30

Table 2: The EDXRF data (net area) obtained for Sample 82

In Sample 82, the colour blue was possibly given by azurite, the associated elements of cobalt could be different depending on the raw materials and the corresponding methods of use. This underglaze cobalt-blue was famous for the colour in the blue-and-white production, it was found in the past studies that the sources could be from either imported European or Chinese local cobalt.[55]

The peaks of iron indicates the use of malachite as pigment for the green colour.

The colour white seems to be the overglaze, iron could act as a strong flux and was commonly added.

Pink have peak of iron, it may advise for a lighter tone of hematite for the colour.

Colour black implied to be a Chinese traditional manganese-iron-copper-cobalt under-enamel black, which origin at Jingdezhen since the mid-15th century. The black colour is produced from the impure cobalt ore on the lead-rich composited enamel during oxidised firing. It was extensively used in the production of overglaze enamel painting porcelain production until the late 19th century.[56]

5.3 Sample 83 – A Chinese Second Half of the 19th Century "Canton" Porcelain Baluster Vase Mounted as a Lamp

The Chinese "Canton" style Porcelain Baluster Vase-Shaped Lamp is from Qing Dynasty (1644 – 1912) at around the second half of 19th century (1850 – 1900), of 84cm tall. The vase have some gilding loss on the handles and on the little dragons.

Its provenance is an Italian private collection.[57]

These porcelain vases developed new function from the appearance of kerosene lamps and later electric lights in the mid-to-late 19th century, the emergence of porcelain vases with lamps embodies the charm and intelligence of Chinese and the West.

Figure 5.5 Facade & Back of Sample 83

5.3.1 EDXRF Results on Pigments of Sample 83

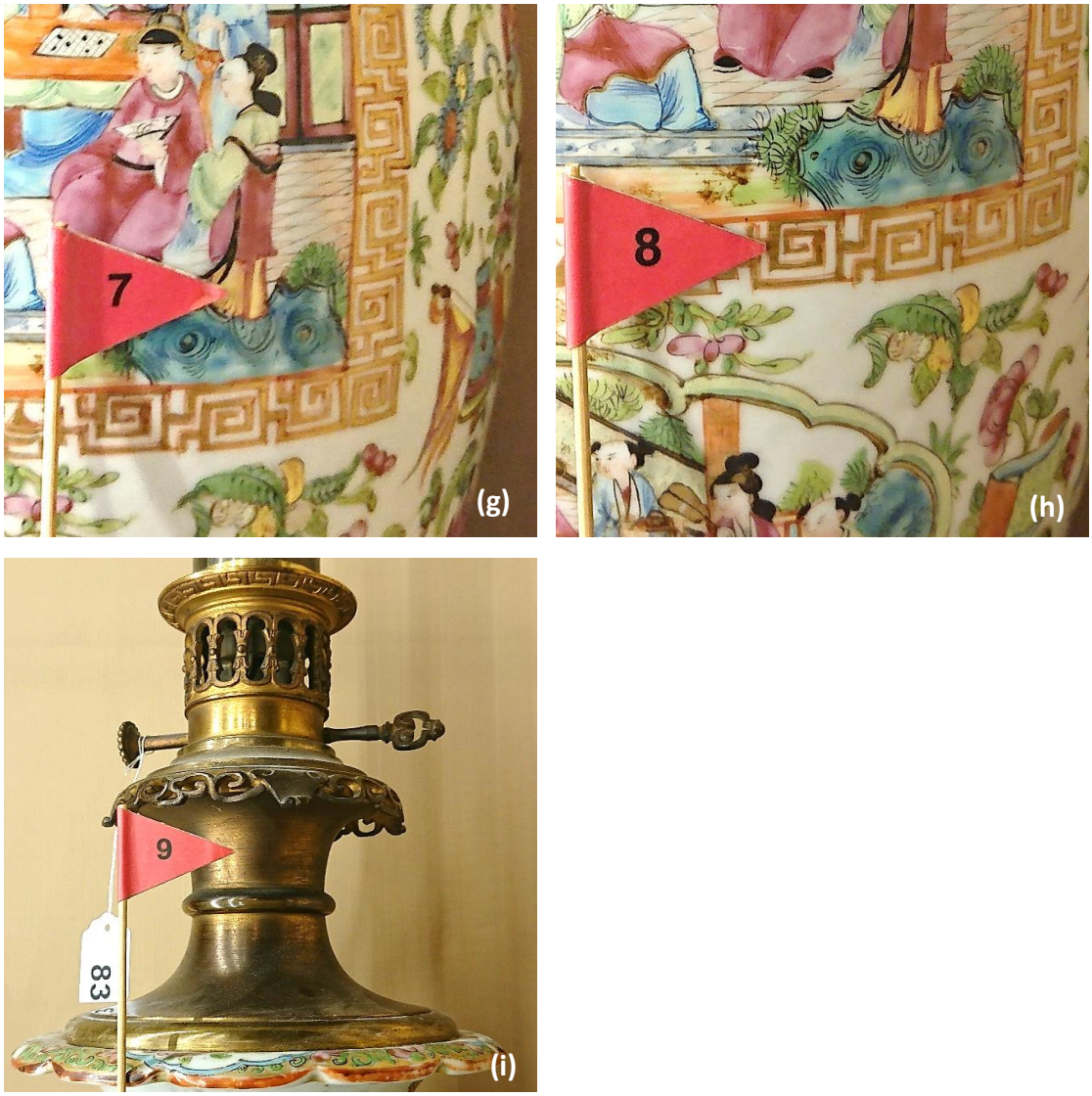


Figure 5.6 (a) Measure 1- blue; (b) Measure 2- green; (c) Measure 3- white; (d) Measure 4- brown; (e) Measure 5- pink; (f) Measure 6- black; (g) Measure 7- yellow; (h) Measure 8- gold; (i) Measure 9- brass

Measure	Colour	Al	S	K	Ca	Mn	Ti	Fe	Co	Cu	Zn	Au	Pb	Accum Time
1	blue	-	-	-	-	-	58	112	381	875	2875	-	6843	36
2	green	-	-	-	-	-	-	55	-	780	102	-	5107	26
3	white	-	-	35	63	-	-	350	68	-	-	-	194	33
4	brown	-	-	4	37	-	-	657	129	-	-	-	111	27
5	pink	-	-	-	13	-	-	58	-	38	63	-	2987	28
6	black	-	-	15	-	81	-	247	60	205	-	-	1107	27
7	yellow	-	55	-	-	-	-	101	-	83	-	-	5273	33
8	gold (with cap)	7	-	-	-	-	-	-	-	-	10	139	54	36
9	brass	-	-	-	-	-	-	-	-	250	180	-	-	44

Table 3: The EDXRF data (net area) obtained for Sample 83

From the spectra of Sample 83, azurite may be the pigment contributed to the colour blue.

Green contains copper, suggesting the use of malachite.

The white colour probably is the porclain glaze, with potassium, calcium and iron added into the lead-glaze as flux.

The colour brown shows a peak in iron, implied the use of hematite, mixed with cobalt for a better colour.

Pink too have a peak in iron pointed to the hematite, a colourant that have been used by the Chinese in a long history, able to present a range of shades from light red to brown depending on the concentration and firing.

The under-enamel black is identified with the presence of manganese, iron, and copper.

The yellow might derived from a lead-based yellow pigment.

The peak of gold gave the colour gold.

The metallic conjunction part of the lamp is made of copper.

5.4 Sample 85 A&B – A Pair of Chinese Second Half of the 19th Century "Canton" Porcelain Baluster Vases

The pair of Chines "Canton" style decorated Porcelain Baluster Vases from Qing Dynasty (1644 – 1912) at the second half of the 19th century, both are of 62 cm tall. The tubular neck with flared mouth and two handle-shaped crouching quadrupeds facing each other, the cylindrical body slightly curved down the shoulders meeting with two pairs of sinuous high-relief dragons. Below composited with rich polychrome and gold decorations, consisting of cartouches with female figures and a combination of "flower and birds" retained on the dense "flowers and butterflies" on the ground. The vases have signs of wear, and gilding loss on the handles and on the little dragons. Its provenance is an Italian private collection.[58]

Figure 5.7 Facade & Back of Sample 85A

5.4.1 EDXRF Results on Pigments of Sample 85A

Figure 5.8 (a) Measure 1- green; (b) Measure 2- blue; (c) Measure 3- brown; (d) Measure 4- white; (e) Measure 5- pink; (f) Measure 6- yellow; (g) Measure 7- black

Measure	Colour	S	K	Ca	Mn	Fe	Co	Cu	Zn	Pb	Accum Time
1	green	60	-	-	8	83	32	341	65	6017	34
2	blue	-	-	-	-	138	161	746	-	7373	40
3	brown	-	39	85	15	945	100	138	-	561	38
4	white	-	94	136	5	691	-	-	-	51	49
5	pink	47	-	20	-	156	-	70	-	2260	31
6	yellow	69	-	-	-	251	-	-	53	5993	42
7	black	-	-	-	241	328	244	1444	173	4219	34

Table 4: The EDXRF data (net area) obtained for Sample 85A

In the spectra of Sample 85A, the green colour was perhaps given from malachite, supported by the peak of copper.

The colour blue contains high amount of copper, likely denoted to azurite, a commonly used traditional pigment in China.

The peak of iron and cobalt in the brown colour showed the possible mixture of hematite with cobalt.

White might came from the porcelain glaze, the presence of potassium, calcium, and iron were likely to be the metallic oxides as flux in the Chinese enamel.

The blending of iron-hematite derived the colour pink.

The yellow colour could be brought by a lead-based yellow, as high content of lead was observed.

Black was proposed to gain from the manganese-iron-copper-cobalt under enamel black.

Figure 5.9 Facade & Back of Sample 85B

5.4.2 EDXRF Results on Pigments of Sample 85B

Figure 5.10 (a) Measure 1- green; (b) Measure 2- blue; (c) Measure 3- brown; (d) Measure 4- white; (e) Measure 5- pink; (f) Measure 6- yellow; (g) Measure 7- black

Measure	Colour	Si	K	Ca	Ba	Mn	Fe	Co	Cu	Zn	Pb	Accum Time
1	green	-	-	-	-	-	145	73	379	78	4884	40
2	blue	-	-	-	-	-	50	61	591	93	5158	29
3	brown	-	48	34	20	73	786	106	308	-	2636	53
4	white	15	73	102	-	55	687	114	90	-	439	43
5	pink	-	-	70	-	-	474	-	74	-	5187	61
6	yellow	-	-	101	-	82	319	-	218	-	9714	67
6	yellow (with high energy)	-	-	-	-	-	12	-	-	21	687	51
7	black	-	-	21	-	40	307	100	230	-	1896	27

Table 5: The EDXRF data (net area) obtained for Sample 85B

For Sample 85B, copper gave the green colour, signify the usage of malachite.
The copper in blue might be adopted from azurite.
The brown colour was shown rich in iron and cobalt, suggesting the employ of hematite red and cobalt blue.
White was the porcelain glaze, silica is the glass form for the glaze, the elements potassium, calcium, and iron were fluxing in the lead enamel.
The iron from red hematite probably made the pink colour by shading.
The high level of lead proposed the colour yellow is from a lead-based yellow pigment.
The measuring with high energy on the same spot supported this found.
The black colour was implied as the Chinese under-enamel black from the peaks of manganese, iron, cobalt, and copper.

The elemental analyses from the pair sample 85A and 85B are very similar, several individual differences were present, more elements were detected from Sample 85B, yet the spectra results gave approximate composition leading to the same possible pigments.

5.5 Sample 100B – A Chinese 20th Century Polychrome Porcelain Plaques with Wooden Frame

This is one of a pair of Chinese Polychrome Porcelain Plaques with Wooden Frame from the 20th century, of 25.5 cm diameter. The plaque is in good condition.
Its provenance is an Italian private collection.[59]

Figure 5.11 Facade of Sample 100B

5.5.1 EDXRF Results on Pigments of Sample 100B

Figure 5.12 (a) Measure 1- green; (b) Measure 2- white; (c) Measure 3- blue; (d) Measure 4- red; (e) Measure 5- yellow

Measure	Colour	S	K	Ca	Mn	Cr	Fe	Co	Zn	Pb	Sn	Accum Time
1	green	50	-	-	-	91	107	122	469	4674	-	34
2	white	-	71	41	-	-	120	-	-	-	-	34
3	blue	81	-	44	34	-	83	586	1229	8273	21	43
4	red	-	26	16	-	-	313	-	148	499	25	25
5	yellow	58	-	-	-	-	80	-	244	5011	17	28

Table 6: The EDXRF data (net area) obtained for Sample 100B

Through the spectra of Sample 100B, the green colour showed peaks of zinc and cobalt, it might be obtained from cobalt green ($CoZnO_2$) pigment, a pigment found in the 18th century.

White colour was possibly the composition of the overglaze, with potassium, calcium, and iron added as flux.

The presence of cobalt and zinc from the colour blue may refer to the use of zinc-cobalt ($(Co,Zn)_2Al_2O_4$), which was discovered in the 18th century.

Red was presumed given by iron in hematite.

The yellow colour contains high content of lead and low tin suggested lead-tin yellow (Pb_2SnO_4) pigment, being an opaque yellow colour it have been identified in the decoration of famille rose overglaze porcelain manufactured from Yongzheng (1722 – 1735) to the early 20th century.[60]

Chromium was found in the composition as impurities in modern Chinese porcelain from the imitated production of the Qing Dynasty in the present Jingdezhen kilns. Thus, this painted porcelain plaque is very likely to be a modern product.

5.6 Sample 149 – A Chinese Mid-18th Century Ink and Colours Wallpaper Panel

The Chinese Ink and Colours Wall Paper Panel from Qing Dynasty (1644 – 1912) at mid-18th century, of height 290 cm by width 122 cm. The scene shows a glimpse of landscape with garden view and pavilions, crowded with male and female figures, drawn on the paper glued on old canvas, with wooden frame.[61]

The painting have signs of humidity, some tears and folds. Its provenance is an Italian private collection.

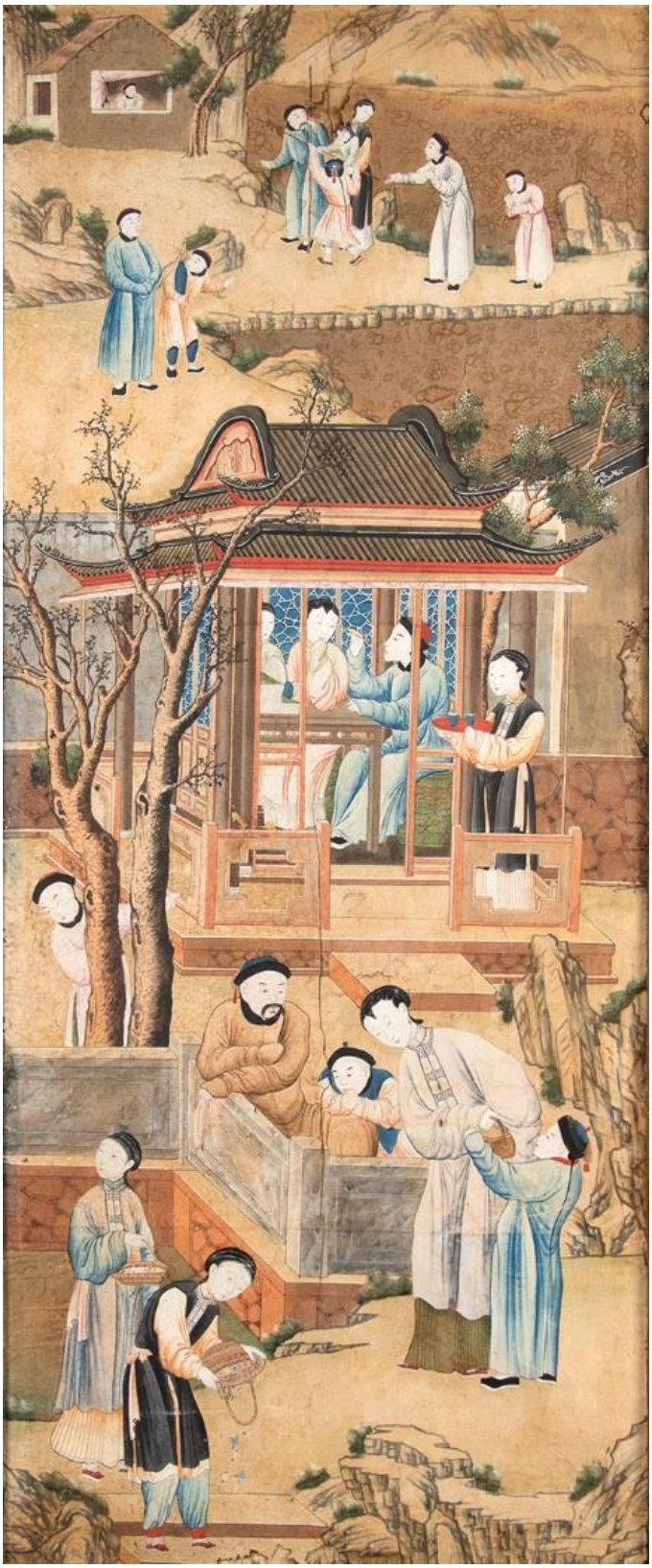


Figure 5.13 Facade of Sample 149

5.6.1 EDXRF Results on Pigments of Sample 149

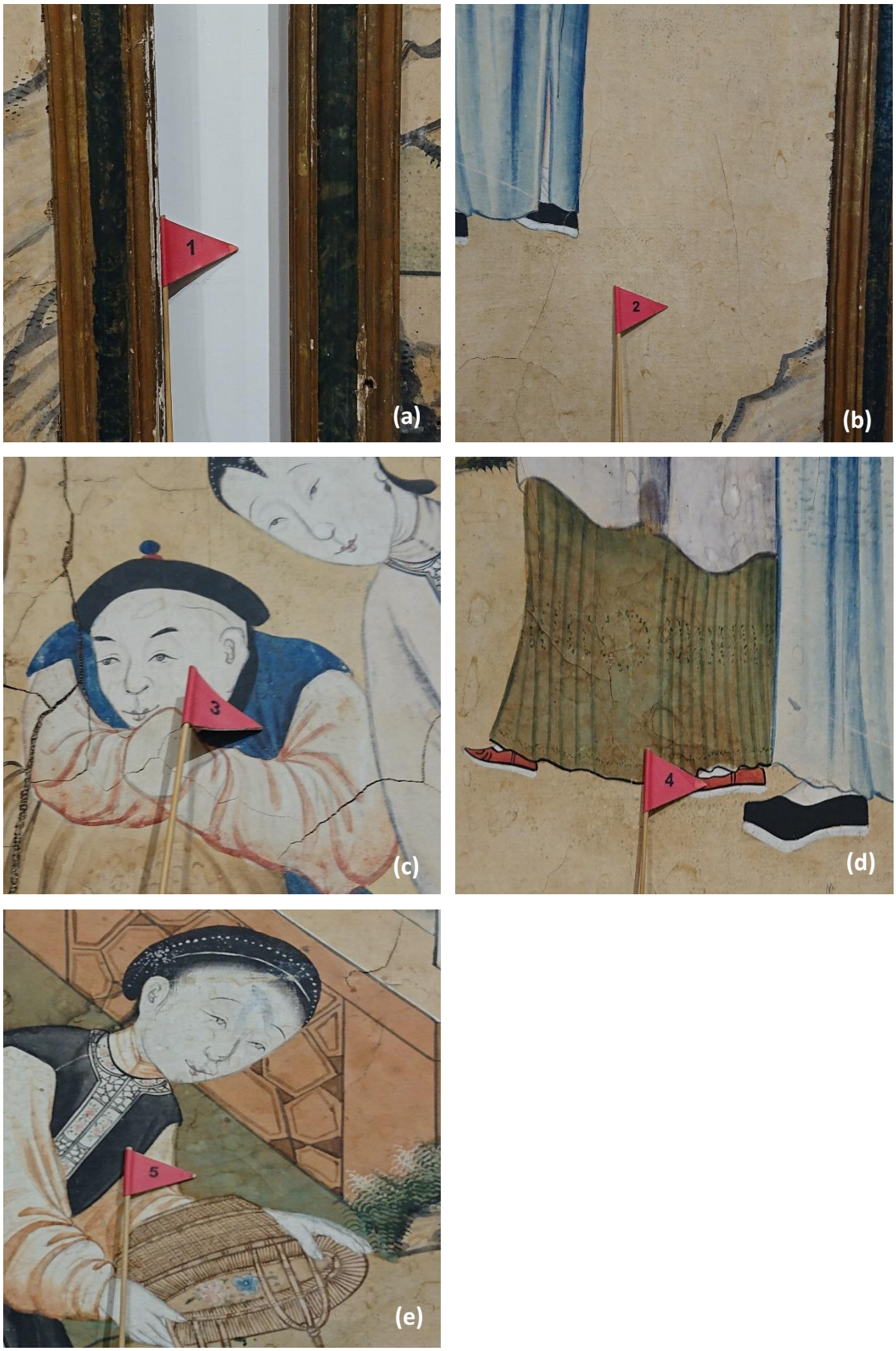


Figure 5.14 (a) Measure 1- wall (blank); (b) Measure 2- background; (c) Measure 3- blue; (d) Measure 4- red; (e) Measure 5- green

Measure	Colour	P	S	Ca	Ti	Mn	Fe	Co	Cu	Zn	Pb	Accum Time
1	wall (blank)	-	-	1028	533	-	52	-	-	60	-	24
2	background	-	19	76	-	29	94	-	-	59	239	32
3	blue	-	168	79	-	-	576	132	-	63	4099	98
4	red	96	-	99	-	-	105	-	72	153	444	33
5	green	-	-	155	-	-	140	-	5748	742	-	60

Table 7: The EDXRF data (net area) obtained for Sample 149

Sample 149 is the only non-porcelain sample in the experiment, being a wall-painting for export created within the same period, the result shown the palette employed in the wallpaper production.

The colour blue was likely to be iron oxide prussian blue ($Fe_7(CN)_{18}$), a western pigment synthesised in the early 18th century. It was imported to Canton for dying purpose in the early 19th century by the English East India Company, but there were record that Chinese might have been manufacturing prussian blue earlier than this date.[62] Prussian blue was found in ink on Chinese paper currencies issued in the Qing Dynasty (1644 – 1912) and coloured drawings in the 19th century.

Red lead (Pb_3O_4) might derived the red colour, it was one of the traditional Chinese colour, and have been found using in paintings either on wall or paper.

High content of copper implied malachite for the colour green.

5.7 Sample 295 – A Chinese 20th Century Polychrome Baluster Vase

The Chinese Polychrome Baluster Vase from 20th century is of 57.7 cm tall. It consists of two sides, the facade is with a group of female figures in a garden landscape, on the other side is an inscription quoting a poem by the famous writer Li Bai (701 – 762) praising the beauty of woman.[63]

The vase have some gilding loss on the handles and chips on the rim.

Its provenance is an Italian private collection.

Figure 5.15 Facade & Back of Sample 295

5.7.1 EDXRF Results on Pigments of Sample 295

Figure 5.16 (a) Measure 1- white; (b) Measure 2- red; (c) Measure 3- blue; (d) Measure 4- yellow; (e) Measure 5- green; (f) Measure 6- grey

Measure	Colour	S	K	Ca	Cr	Mn	Fe	Co	Cu	Zn	Pb	Sr	Accum Time
1	white	-	65	71	-	-	73	-	-	-	-	8	27
2	red	83	89	171	-	-	362	-	169	-	488	87	32
3	blue	78	68	88	473	-	99	252	78	983	1065	55	32
4	yellow	95	-	87	-	-	101	-	106	651	1596	-	29
5	green	91	-	67	127	-	119	176	-	344	976	-	26
6	grey	49	71	94	105	47	244	116	16	-	400	51	24

Table 8: The EDXRF data (net area) obtained for Sample 295

From the result of Sample 295, the measure on colour white also indicated the glaze of the porcelain, the peaks of potassium, calcium, and iron might be the metal oxides added into the ceramic glazes as flux, therefore to lower the enamel melting temperature.

Iron detected from the red colour revealed the possible use of hematite.

The colour light blue was probably obtained from cobalt-zinc blue, chromium were present for a more smooth and opaque colour.

High amount of lead shown in the yellow colour suggested the usage of a lead-based yellow pigment.

The presence of zinc and cobalt proposed to cobalt-green ($CoZnO_2$).

The grey colour was assumed to be the manganese-iron-copper-cobalt under enamel black.

With chromium, this vase very likely is a modern Chinese porcelain reproduction imitating the form of production from Qing Dynasty.

5.8 Sample 296 – A Chinese Early 20th Century Large "Famille Rose" Figure of ShouLao

The large Chinese Famille Rose Figure of ShouLao (Chinese God of Longevity) from the early 20th century, of 61 cm tall. It is richly painted in bright enamels, the dresses were decorated with fruits, objects and animals with good omen. The figure is in good condition.

It was acquired before 1975.[64]

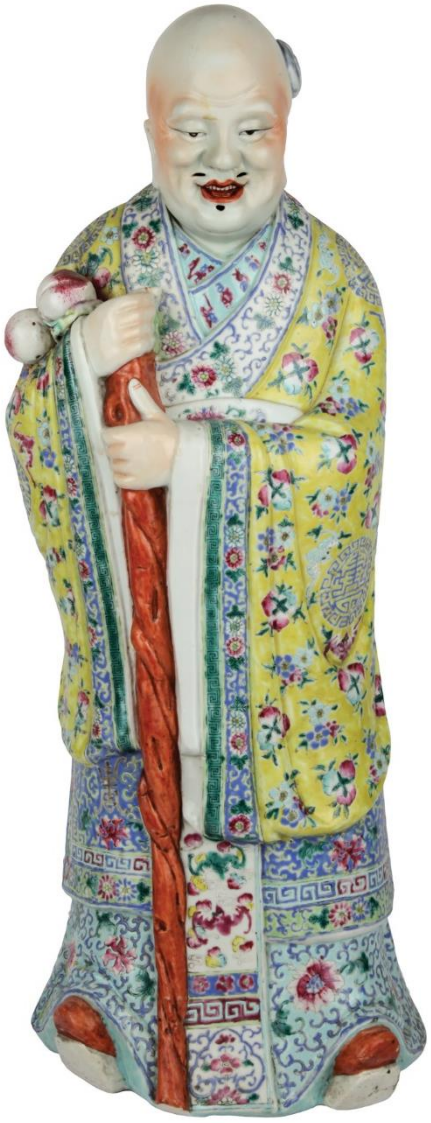


Figure 5.17 Facade & Back of Sample 296

5.8.1 EDXRF Results on Pigments of Sample 296

Figure 5.18 (a) Measure 1- yellow; (b) Measure 2- blue; (c) Measure 3- green; (d) Measure 4- red

Measure	Colour	S	K	Ca	Fe	Co	Cu	Zn	Pb	Accum Time
1	yellow	180	-	-	305	-	277	-	13662	85
2	blue	153	76	-	214	363	240	-	13064	72
3	green	74	-	-	102	-	1686	86	5567	23
4	red	28	-	44	942	134	86	-	1260	23

Table 9: The EDXRF data (net area) obtained for Sample 296

In the spectra of Sample 296, the high peaks of lead in yellow colour advised the use of a lead-based yellow pigment.

The colour blue contains cobalt, which signified to generate the colour.

High level of copper were detected in the colour green, could be obtained by the pigment malachite.

The red colour is rich in iron, hematite might be the source of the colour.

6. Discussion and Further Questions

Although the production of these significance Chinese enamelled porcelain was during the 16th to 20th century, there were no record of the chemical composition and recipe of the porcelain and pigment in the Chinese literature. The current understanding of Chinese Qing porcelain manufacturing was based upon the letters written by the French Jesuit missionary Père d'Entrecolles dated in 1712 and 1722, where he have documented the production practice in many aspects.

The modelling of the sampled porcelain category came from the assimilation with foreign pigments and created the colourful decorations, which have a high artistic and scientific value in the global influence.

Hence, it is necessary to analyse the pigments by scientific means, there are diverse studies on Chinese porcelain but little of them were performed by EDXRF spectroscopy, the data from this dissertation are also important for the protection and recognition of the presence artwork.

In this dissertation, the pigments on porcelain and wallpaper painting were analysed by portable EDXRF, the results provided basic information on the formula of pigments, and could offer as a reference and contribute to related studies in porcelain production.

6.1 The Palette

6.1.1 On Porcelain Decoration

The painted enamelled porcelain is rich in colour, with the use of portable EDXRF, it can effectively detect the chemical composition and identification of multiple pigments, which can approximately determine the production technique and the period of the artwork.

From the 7 samples' result, metal oxides copper (Cu), iron (Fe), and manganese (Mn), were the three primary colouring agents used in the overglaze colouring materials during the Qing Dynasty (1644 – 1912).[65]

The chemical information demonstrated that copper (Cu) generated green, iron (Fe) is the main colourant in red, manganese (Mn) gave black, cobalt (Co) led blue, and a lead (Pb) -based pigment for yellow.

Being a colouring element, iron (Fe) is present in various colours such as green and yellow, considered it is possible to have an effect of tuning the colours.

There are three blue coloured samples, Sample 77-2, 82-1, and 100B-3, recorded with peaks of manganese (Mn) and iron (Fe), from the amount of manganese and iron, which are impurities naturally exist in the cobalt ores, the composition could suggest the source of the blue pigment cobalt (Co) was employed. The three samples all containing high iron (Fe) and low manganese (Mn), according to literature, it refers to the application of imported European cobalt.[66] Studies have reported that Europe has

been exporting cobalt to China in the 18th and 19th century for the use in porcelain production.[67]
It has also been described that the lead-based yellow pigments were introduced into China since Kangxi period in the 17th century, replacing the transparent iron-yellow enamels, and began the use of opaque yellow enamels in the overglaze porcelains.[68]
The creation of famille verte and famille rose collection were from the influence by the practice from Europe, so the same may applies to the pigments adopted.

Through portable EDXRF, the chemical characterisation of the pigments have narrowed the range of the sources and provided an approximate dating. In this experiment, the date of production of all the 7 porcelain samples were no earlier than the 17th century, which is consistent with the style and historical content.

In the samples of white: Sample 83-3, 85A-4 & 85B-4, 100B-2, and 295-1, trace amount of potassium (K), calcium (Ca) and iron (Fe) were detected, they are part of the composition of the glaze and showed the technology applied in the porcelain manufauring. These metal oxides were added as fluxes to lower the silica's high melting point and to archieve the ideal physical properties of glaze.[69]

One of the characteristics of these new porcelain families was the enamel of opaque lead-based overglazes, the unique features of the new colours are its opacity, it can be used alone or, have the ability to be mixed with white to form various shades.[70]
Opacifiers were applied in porcelain and enamel in a long history, for the glaze opaque or translucent. The white colourants may serves as opacifiers or pigments.[71]
All the samples shown high content of lead (Pb), it is widely distributed, and lead oxide was added as the major flux to lower the melting point of the enamel and to be sintered at a lower temperature.
The presence of lead (Pb) may also be used as opaque white, which is a lead-based arsenic white. Opaque white is mainly composed of silica (Si), lead (Pb), and arsenic (As),[72] arsenic was also found as a major colouring element for the whiteness in Chinese porcelain manufacturing. In previous studies, high content of silicon (Si) and arsenic (As) are detected in the relation of opaque white area, however these two elements were not found in this investigation, alternative and further analysis may require.
The high amount of lead (Pb) in the samples in this case maybe correspond to its usage as lead-glaze, which have properties of a lower melting temperature (700~ 800°C) and to retain the contours and alinement of the appearance of the porcelain. Supplementary investigation would gave more details on the function of lead.

Previous research have found metal impurities such as Chromium (Cr) and Uranium (U) in the colouring element from modern Jingdezhen porcelain, which were not present during the Qing production. This feature can be used to identify the

authenticity of the glazed porcelain. The two samples (Sample 100B and 295) that recognised to be a 20th century product both catered this found, EDXRF have detected chromium in the two samples, conjointly with typology and literature, offered a support and confirmation to the dating and authenticity.

The properties of some pigments differ, and thus the method of performance is different. The pigments applied for famille rose decoration were prepared from a variety of metal oxides and therefore required extra conscious to control, this gave complexity in coloration. The brightness of pigments is the main difference between the painting decoration and the colour enamel. Whilst before firing, the colours of the decoration and the colour enamel do not appear obvious different and both the properties are fundamentally identical.[73]

Famille rose collection is one of the representations of the imperial wares during the Qing Dyanasty (1636 – 1912), it demonstrates a different production technique with the oil-based colour style, showing in a sense of western manner. The transition from transparency to opaque appearance was revelatory in porcelain production and greatly extended the content of Chinese ceramics.[74] Canton style was developed as a branch of famille rose, decorated in standard patterns, and supplied under the demand of European merchants.
It signified the process of the transfer of technology and innovation between Europe and China, and form a circulation of the trading of knowledge and goods under the growing global influence.

6.1.2 On Wallpaper Painting

Contrariwise, Chinese wallpaper-painting panel did not receive much attention than Chinese porcelain, little research were made, maybe due to the lack of historical literature. This could be a potential category for in depth studies on Chinese artwork and export trade from a different approach. The experiment done in this dissertation may gave an idea on later research regarding Chinese wallpaper painting in the 18th century.
The Chinese wallpaper painting set on the panel were painted in a typical Chinese means whereas meeting the scale of foreign houses, same with the porcelain product, a demonstration of western form within the shape of traditional chinese method.
The result obtained from the wallpaper painting was showing a combination of usage of local and imported pigments, common with the porcelain production, presumably with the continuous use of traditional Chinese colours, [75] which also the ones employed in the porcelain production, such as lead-red and copper-green, but as well as a new imported iron-blue.

This brought up the assumption that the wallpaper painting and porcelain production, both shared a similar palette formed with native and foreign pigments, perchance from the same line of workshop dedicated to manufacturing export merchandise which was able to reach newly imported pigments.

6.2 Limitations

Through the examination carried out by the portable EDXRF, the porcelain and wallpaper painting pigments could be revealed, EDXRF did help to narrow down and provided suggestions on the probability of pigments, nevertheless having only this instrumentation is not possible to specify the exact pigment used in the palette.

However, the application of portable EDXRF in this study have shown several limitations. The coloured pigments containing high concentration of lead emitted high content of lead-excited peaks interference the characteristic peaks of other elements, which made the quantitative analysis of the spectra difficult. In the high-lead matrix also caused the low sensitivity of the light elements.[76]

For further research, additional apparatus would needed as a support, for example Raman spectroscopy, another sensitive and non-destructive technique for furhter identification.

7. Conclusion

Auction is not only a location for buying and selling, but also fancy public events that stimulate social and academic interaction. It does not exist solely for the exchange of items alone, it also serves as a platforn for the creation of knowledge.
Science is becoming more crucial as a supporting component on the falsification and authentication of the work of art. Science do not declare authenticity, it provide physical evidence to support the attribution and the date of the artefact, to be used as additional data with other specialists' area of expertise. When it is unable to make a judgement merely based on the artistic style and aesthetic value, the introduction of scientific investigation and art historical evidence composed a full coverage on the information of the work of art, leading to the successful final determination of authenticity.

Enamelled porcelain has been the mainstream of Chinese porcelain since the Qing Dynasty, the importance on its unique craftsmanship led to its significant status as one of the Jingdezhen's unique traditional production. In recent years, these porcelain are popular among auction houses and have been sold at high prices.
This thesis focused on the analytical investigation of portable EDXRF on the paint of famille rose, famille verte, and Canton style porcelain, together with a wallpaper painting panel have preliminary interpreted the major pigments, and appeared to be consistent with the traditional Chinese pigments used by craftmen. The identified pigments thence offered factual evidence on the extent of the date and supported the value of the artefacts.
In present of this dissertation, portable EDXRF would be an adequate enhancement in an auction house, its advantages of non-destructive, fast, and high accuracy allowed it to be applied on various form of samples for multi-elemental analysis. It is very suitable for a composition examination of different artefacts for identification and dating.
Nevertheless, in the scientific analysis perspective, the single use of EDXRF is not sufficient to effectively answer the recognition of the pigments, it would be necessary to have a combined archaeometry method to achieve a mutual and comprehensive confirmation.

Appropriate instruments and artistic knowledge are surely pivotal to solving the increasing problems facing today in the Art Market. It is important to exchange and share openly the information data and studies in the certification of the work of arts, as it would be helpful to judge the effectiveness of the techniques and settings of interpretation applied during the tests. It is without a doubt that, a proper scientific analysis of the work of art can offer verifiable evidence of for forgeries. Through the application of scientific investigation in auction houses and museums, it attempt

trying to control and reduce the flow of forgeries, and to overcome the complicity of the art market in the face of self-interest.

In conclusion, the scientific contribution allow comparisons and mutual comment between subjective and objective evaluation, resulting in a greater accuracy to the 'truth' hidden behind the work of art. It is a supporting pillar of the formation for the final verdict on the authentication, offering an integrated report with comments from art historians, curators, and any related experts.
Auction house serves as a stage where buyers, sellers, and knowledgable agents come together to appreciate art of different values, the multi attempt of historical and scientific application supporting each other, to pursue the possible truth behind a piece of art.

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Appendix 1:	Bertolami Fine Art Internship Itinerary			
			9/5/2019 (Thu) Hours: 10:30—19:00 -Organise and categorise photos of art objects, which were to be posted online and printed catalogue for the auction.	**10/5/2019 (Fri)** Hours: 10:30—19:00 -Continued on the remaining photos. -Integrate information of Ivory and Coral objects from documents (for CERT and license application). -Modify objects details in the excel document.
13/5/2019 (Mon) Hours: 10:00—19:00 -Browse through items in the auction collection that may be analyse. -Onlook measuring ivory and coral items for CITES certificate. -Onlook the typesetting of the printed catalogue.	**14/5/2019 (Tue)** Hours: 10:00—19:00 -Collect and organise the mailing list for newsletter for the auction.	**15/5/2019 (Wed)** Hours: 10:00—19:00 -Continued with the mailing list. -Search for potential customers (gallerys/auction houses/private collectors) and add to the mailing list.	**16/5/2019 (Thu)** Hours: 10:00—19:00 -Re-organise the items' ID as new items were added. -Assist with item's descriptions translation.	**17/5/2019 (Fri)** Hours: 10:00—19:00 -Assist with organisation and description of antique photographs.

20/5/2019 (Mon) Hours: 10:00—19:00 -Assist with organisation and description of antique photographs.	**21/5/2019 (Tue)** /	**22/5/2019 (Wed)** Hours: 10:00—19:00 -Assist with organisation and description of antique photographs.	**23/5/2019 (Thu)** Hours: 10:00—19:00 -Assist with organisation and description of antique photographs.	**24/5/2019 (Fri)** /
27/5/2019 (Mon) Hours: 10:00—19:00 -Assist with organisation and description of antique photographs.	**28/5/2019 (Tue)** Hours: 10:00—14:00 -Assist with organisation and description of antique photographs.	**29/5/2019 (Wed)** Hours: 10:00—19:00 -Assist with organisation and description of antique photographs.	**30/5/2019 (Thu)** Hours: 10:00—19:00 **-**Update/upload items descriptions on websites.	**31/5/2019 (Fri)** Hours: 10:00—19:00 -Assist with organisation and description of antique photographs.
3/6/2019 (Mon) Hours: 10:00—19:00 -Assist with organisation and description of antique photographs.	**4/6/2019 (Tue)** Hours: 10:00—19:00 -Assist with organisation and description of antique photographs. -Prepare, organise, and set-up for the auction exhibition.	**5/6/2019 (Wed)** Hours: 10:00—19:00 -Prepare, organise, and set-up for the auction exhibition.	**6/6/2019 (Thu)** Exhibition Day Hours: 10:00—19:00 -Prepare, organise, and set-up for the auction exhibition. **-**Label the lot number of all the items in the auction. -Customer service.	**7/6/2019 (Fri)** Exhibition Day Hours: 10:00—19:00 **-**Label the lot number of all the items in the auction. -Customer service.

8/6/2019 (Sat) Exhibition Day Hours: 10:00—19:00 -Customer service.	**9/6/2019 (Sun)** Exhibition Day Hours: 10:00—19:00 -Customer service.			
10/6/2019 (Mon) Exhibition Day Hours: 10:00—19:00 -pEDXRF analysis of selected samples for thesis. -Customer service.	**11/6/2019 (Tue)** Day of Auction 64 Hours: 10:00—19:00 -Customer service.	**13/6/2019 (Wed)** Hours: 10:00—19:00 -Arrange and set-up the exhibition room for the next auction.	**14/6/2019 (Thu)** /	**15/6/2019 (Fri)** /
17/6/2019 (Mon) Hours: 10:00—19:00 -Prepare and set-up for exhibition. -Assist with organisation and description of antique photographs. -Scan the antique photographs for documentation.	**18/6/2019 (Tue)** Hours: 10:00—19:00 -Assist with organisation and description of antique photographs. -Assist with customers whom wanted to sell their collection.	**19/6/2019 (Wed)** Hours: 14:00—19:00 -Assist with organisation and description of antique photographs. -Scan the antique photographs for documentation.	**20/6/2019 (Thu)** Hours: 10:00—19:00 -Assist with organisation and description of antique photographs. -Scan the antique photographs for documentation. -Customer service.	**21/6/2019 (Fri)** Hours: 10:00—19:00 -Assist with organisation and description of antique photographs. -Scan the antique photographs for documentation. -Customer service.

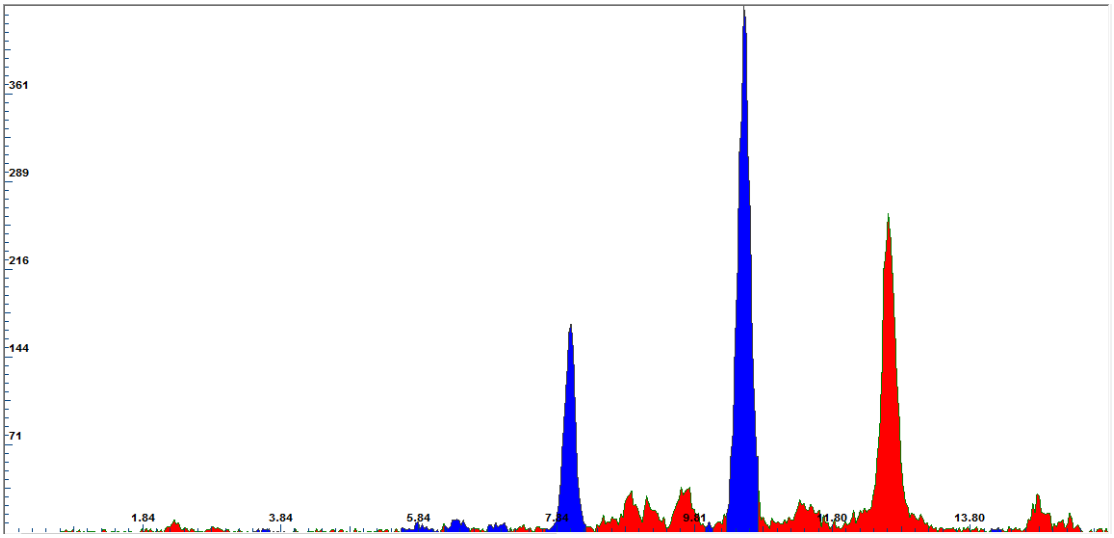
24/6/2019 (Mon) Hours: 10:00—19:00 -Assist with organisation and description of antique photographs. -Scan the antique photographs for documentation.	**25/6/2019 (Tue)** Hours: 10:00—19:00 -Assist with organisation and description of antique photographs. -Scan the antique photographs for documentation.	**26/6/2019 (Wed)** Hours: 10:00—19:00 -Assist with organisation and description of antique photographs. -Scan the antique photographs for documentation.	**27/6/2019 (Thu)** Hours: 10:00—19:00 -Assist with organisation and description of antique photographs. -Scan the antique photographs for documentation.	**28/6/2019 (Fri)** Hours: 10:00—19:00 -Assist with organisation and description of antique photographs. -Scan the antique photographs for documentation. -Assist with description of silver accessories from Liao Hmong.
22/7/2019 (Mon) Hours: 11:00—13:00 -pEDXRF analysis on silver accessories from Liao Hmong, and silverwares from Europe.				

Required hours: ≥150 hours (3 credit)

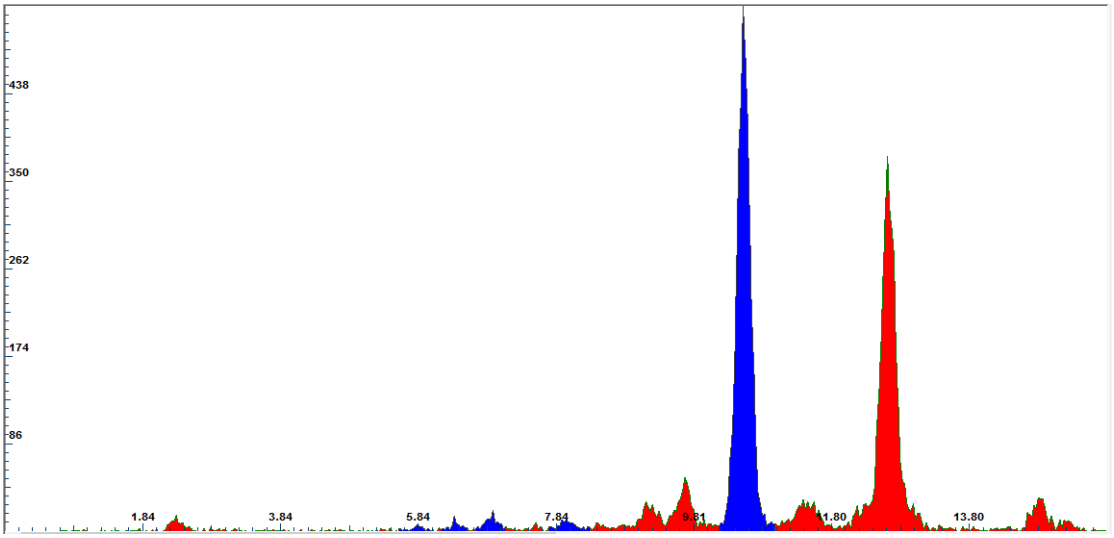
Appendix 2

Spectra of EDXRF on Sample 77

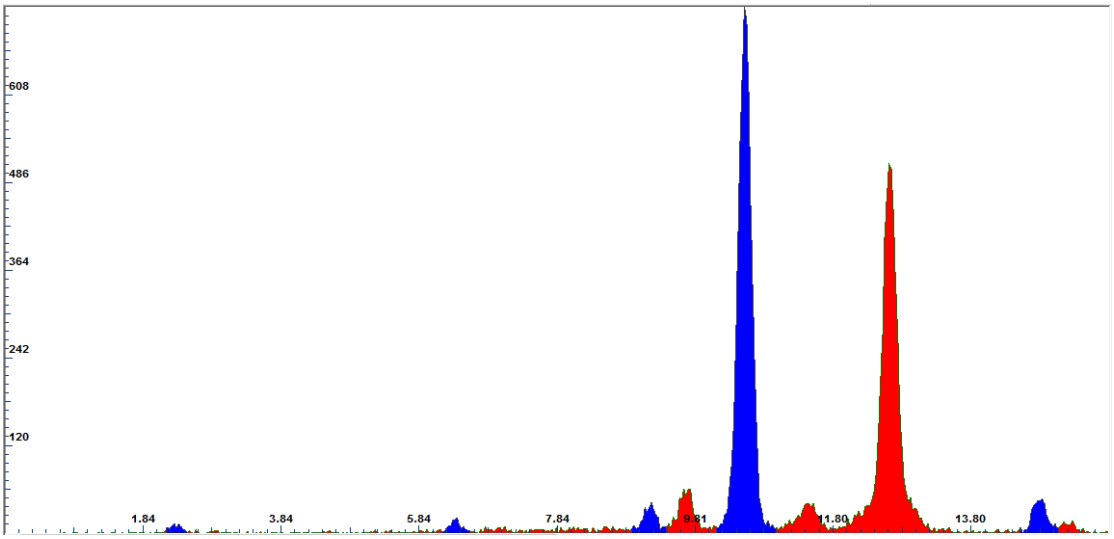
Measure 1 – green



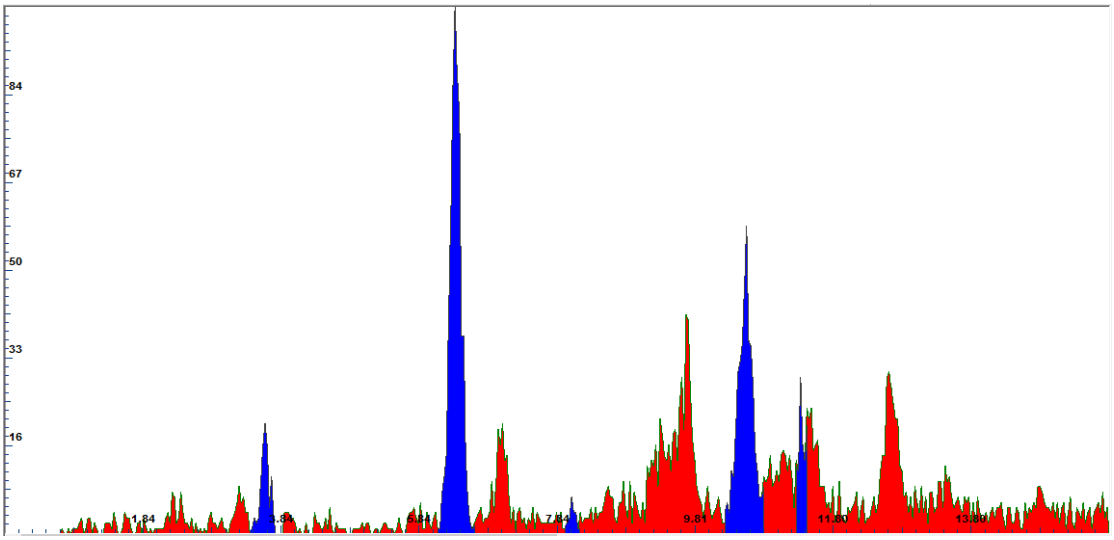
Measure 2 – blue



Measure 3 – yellow

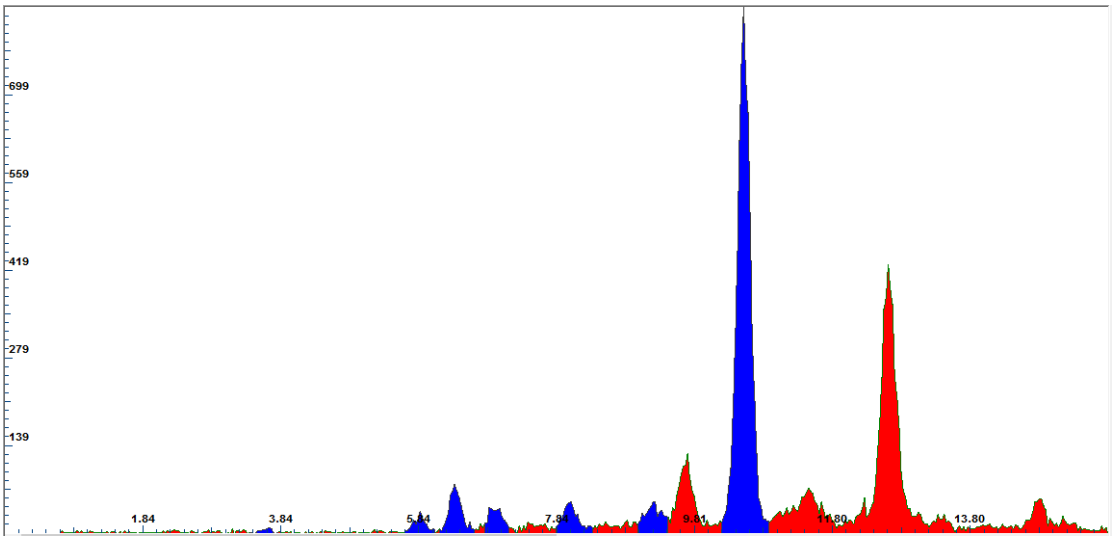


Measure 4 – red

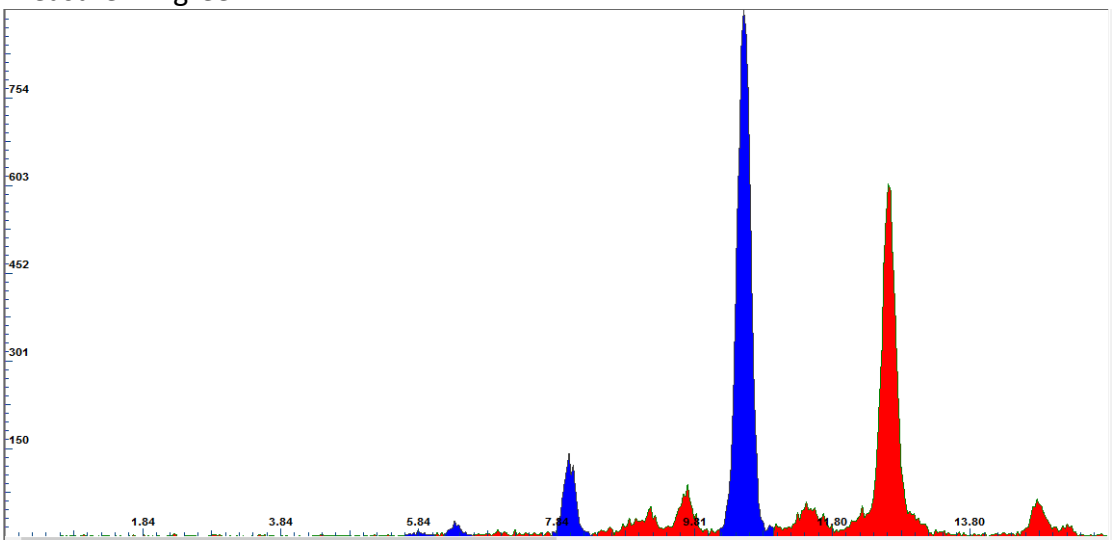


Spectra of EDXRF on Sample 82

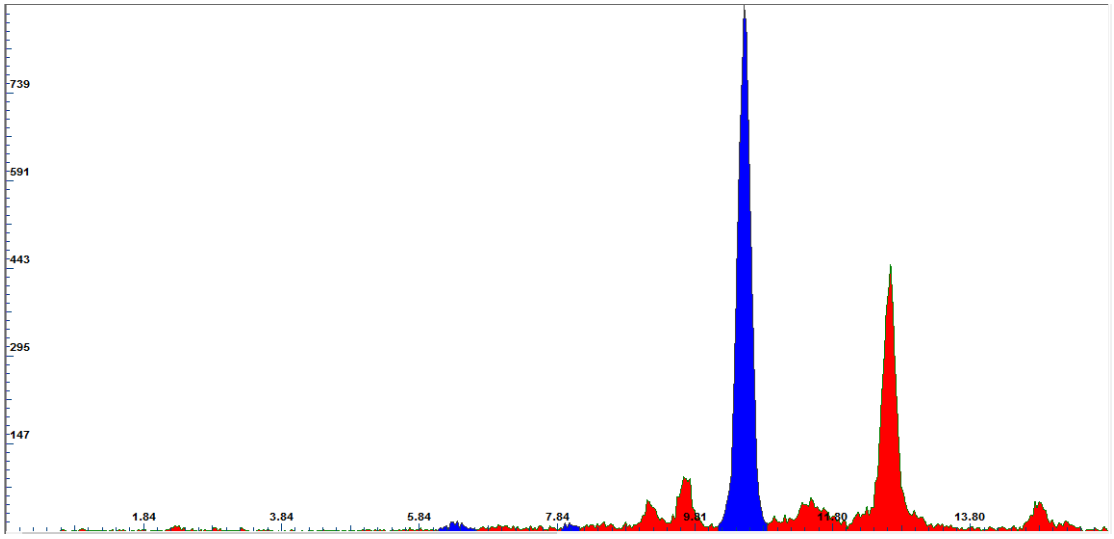
Measure 1 – blue



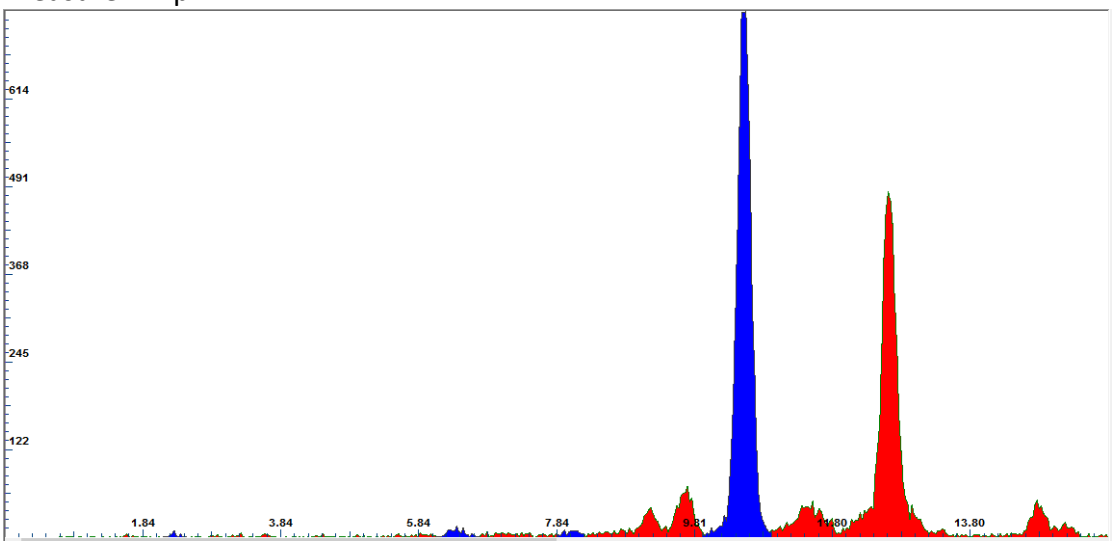
Measure 2 – green



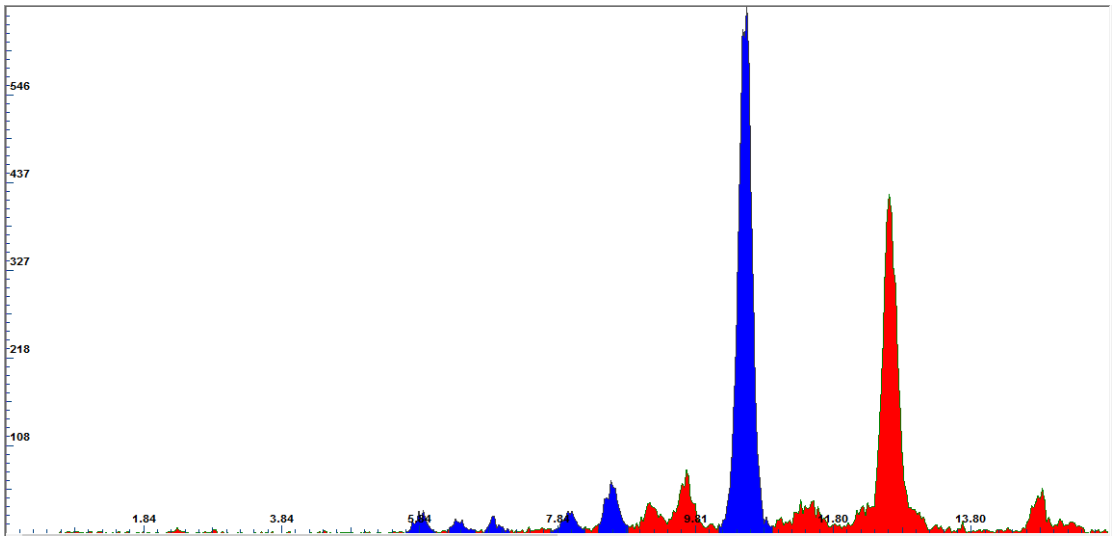
Measure 3 – white



Measure 4 – pink

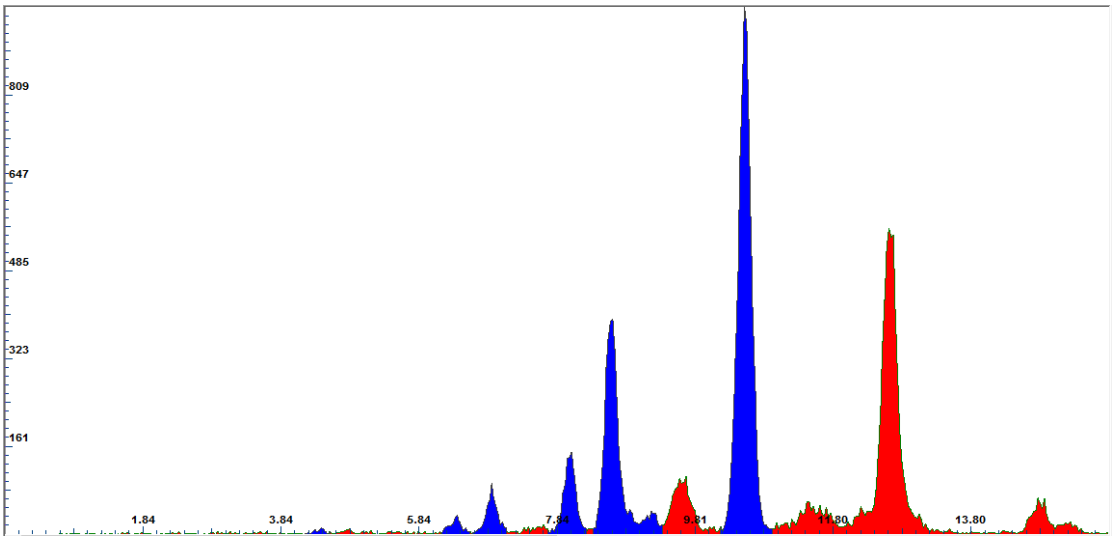


Measure 5 – black

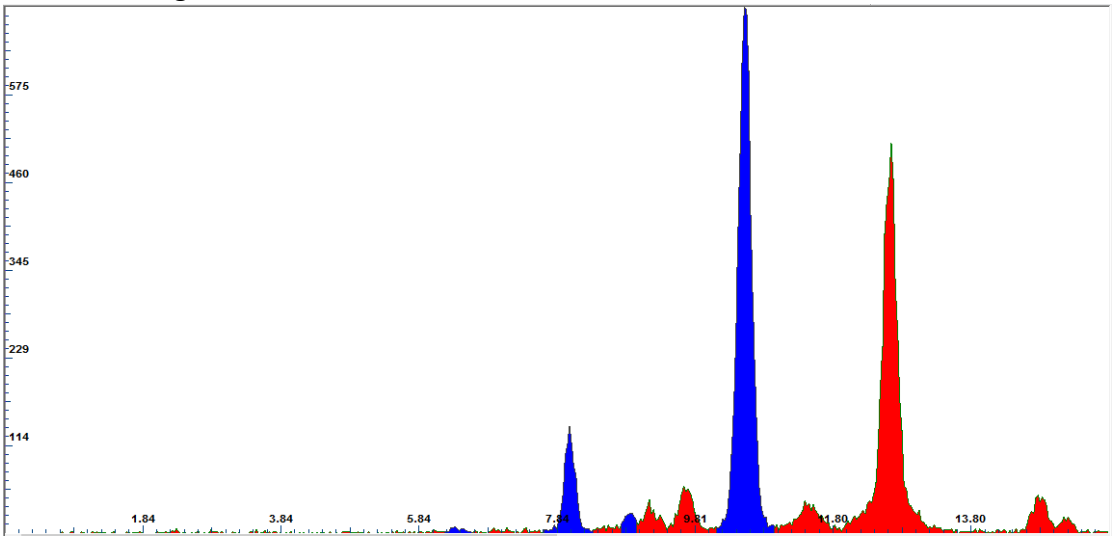


Spectra of EDXRF on Sample 83

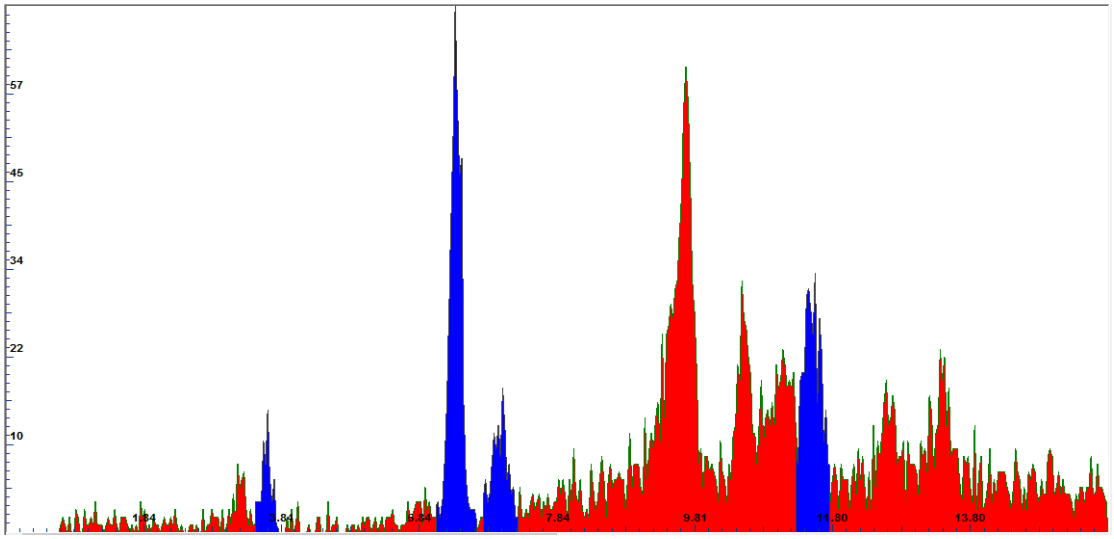
Measure 1 – blue



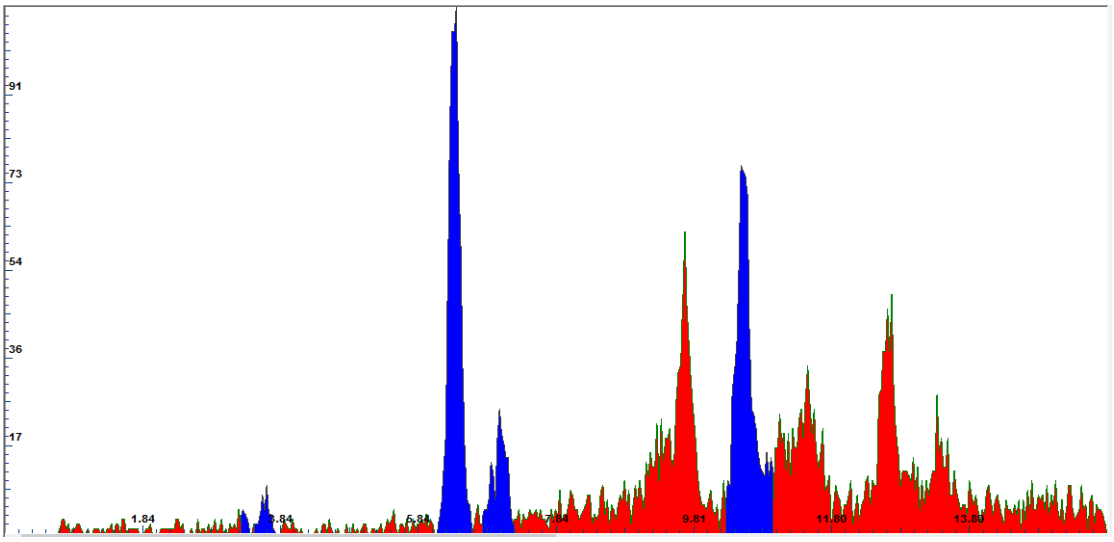
Measure 2 – green



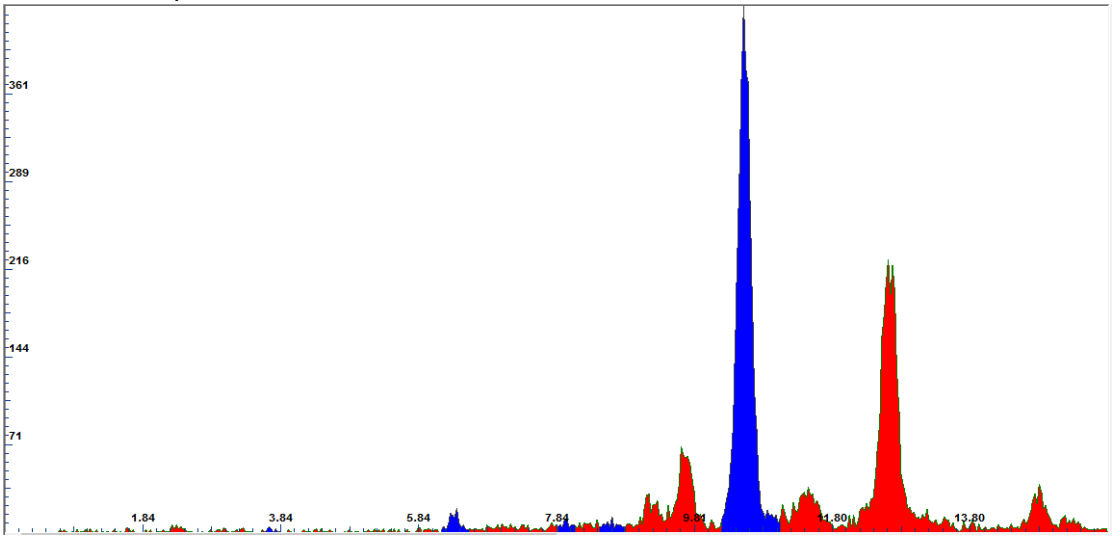
Measure 3 – white



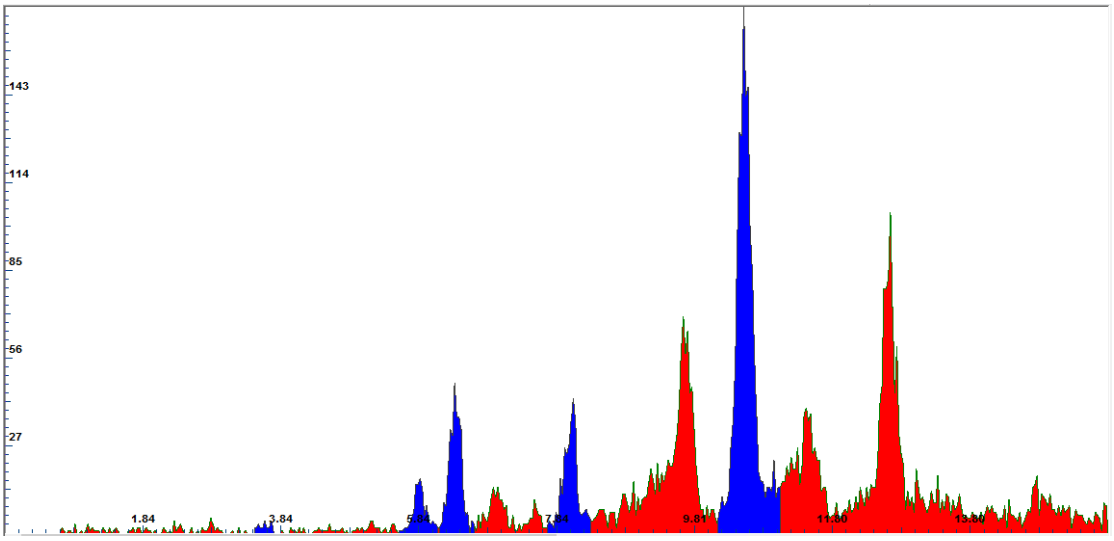
Measure 4 – brown



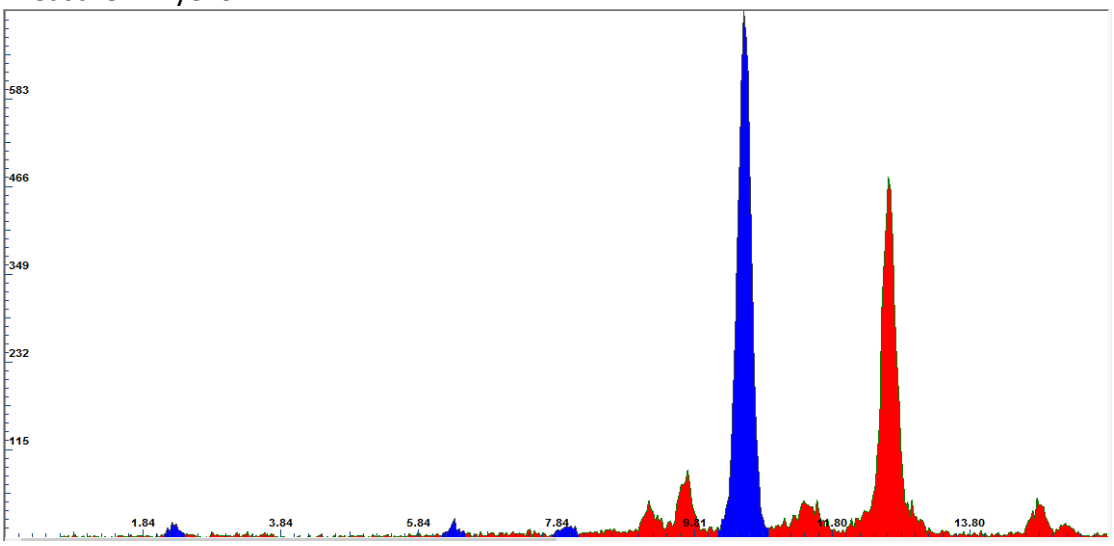
Measure 5 – pink



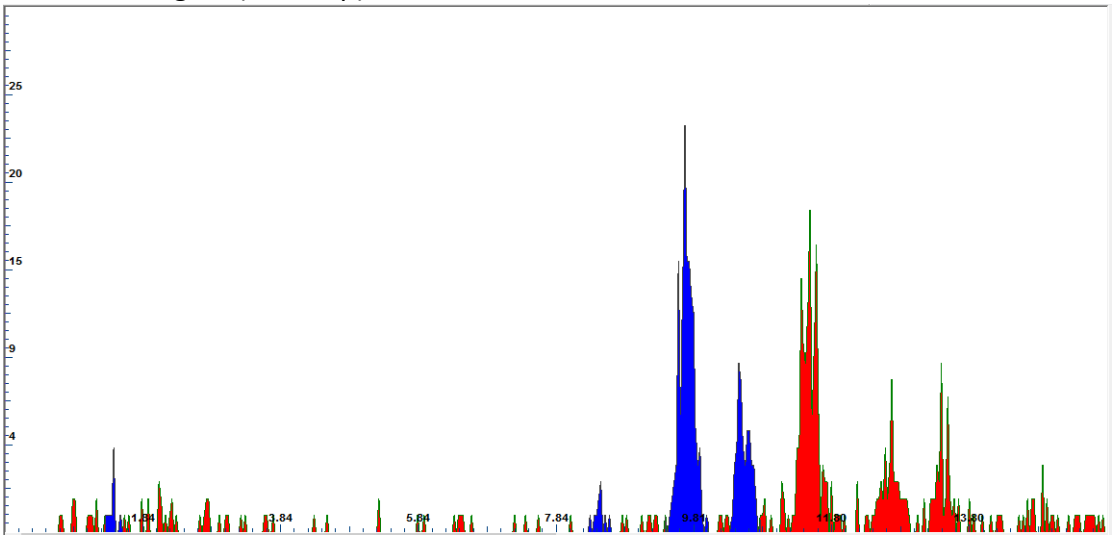
Measure 6 – black



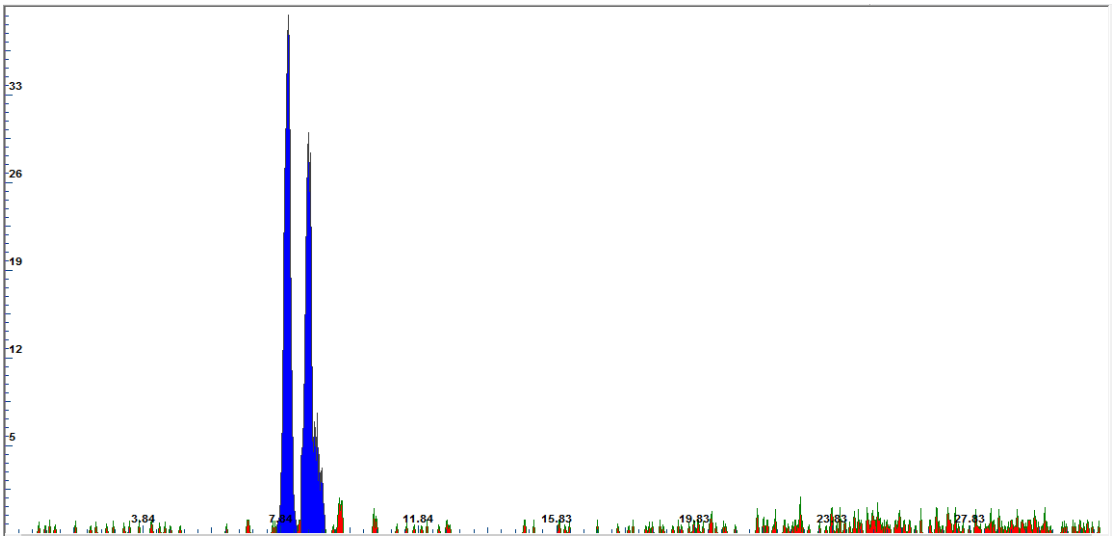
Measure 7 – yellow



Measure 8 – gold (with cap)

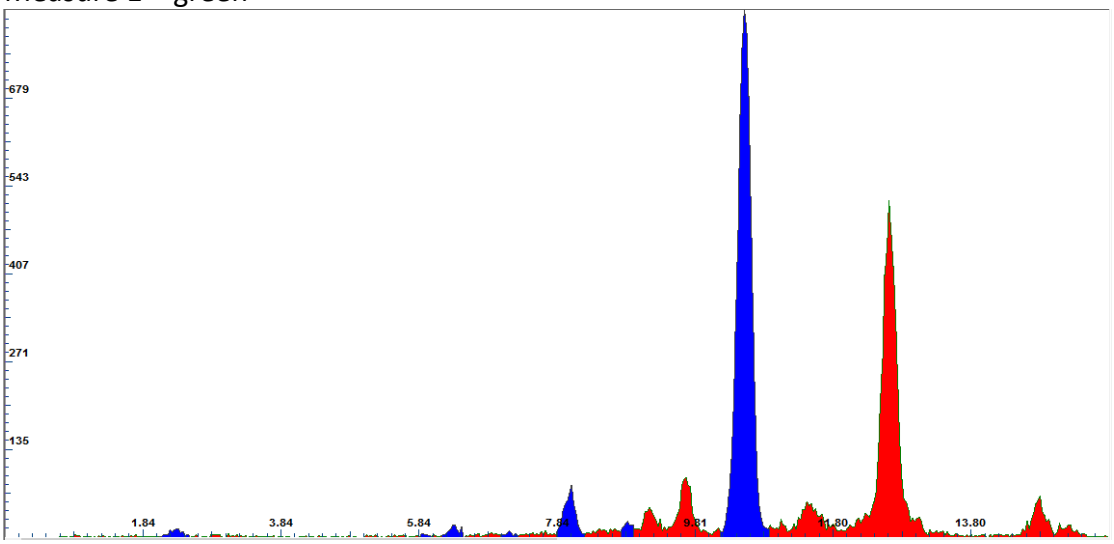


Measure 9 – brass

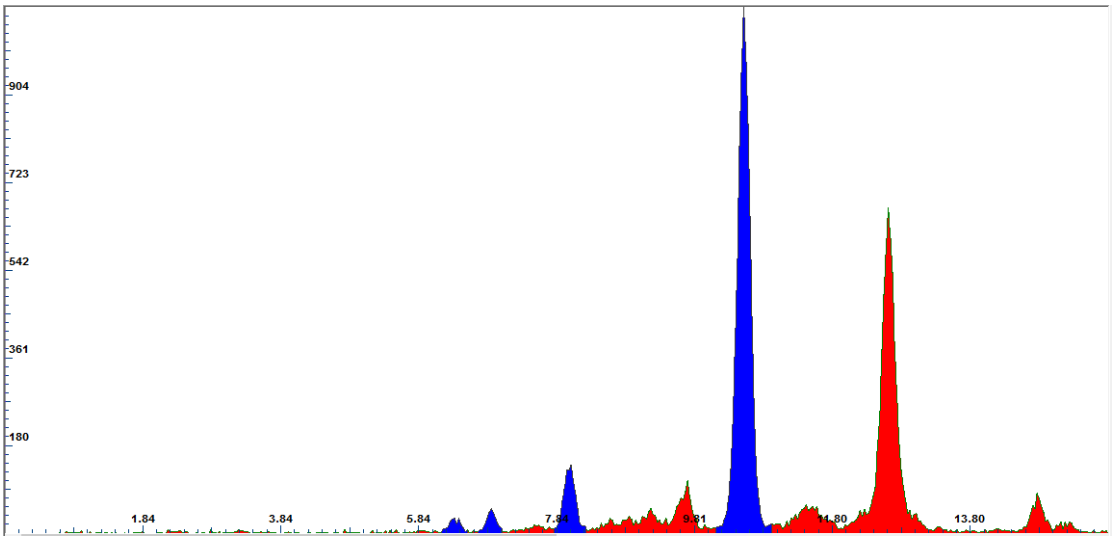


Spectra of EDXRF on Sample 85A

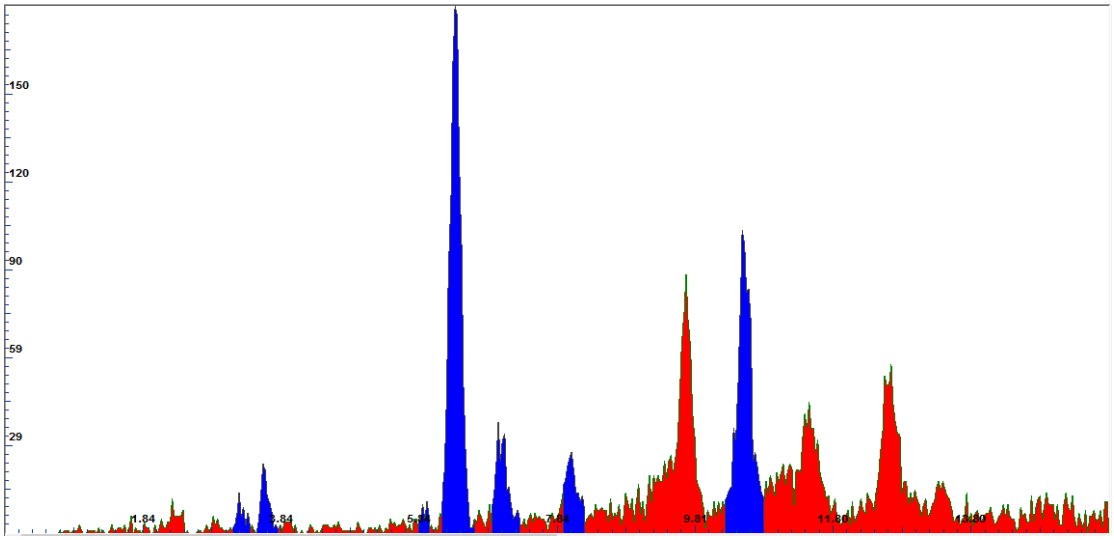
Measure 1 – green



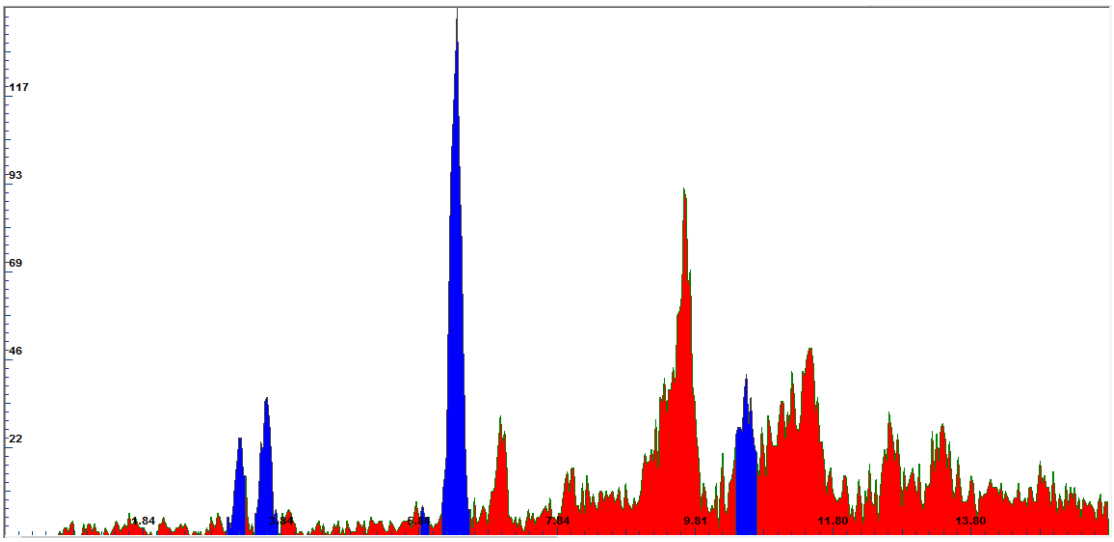
Measure 2 – blue



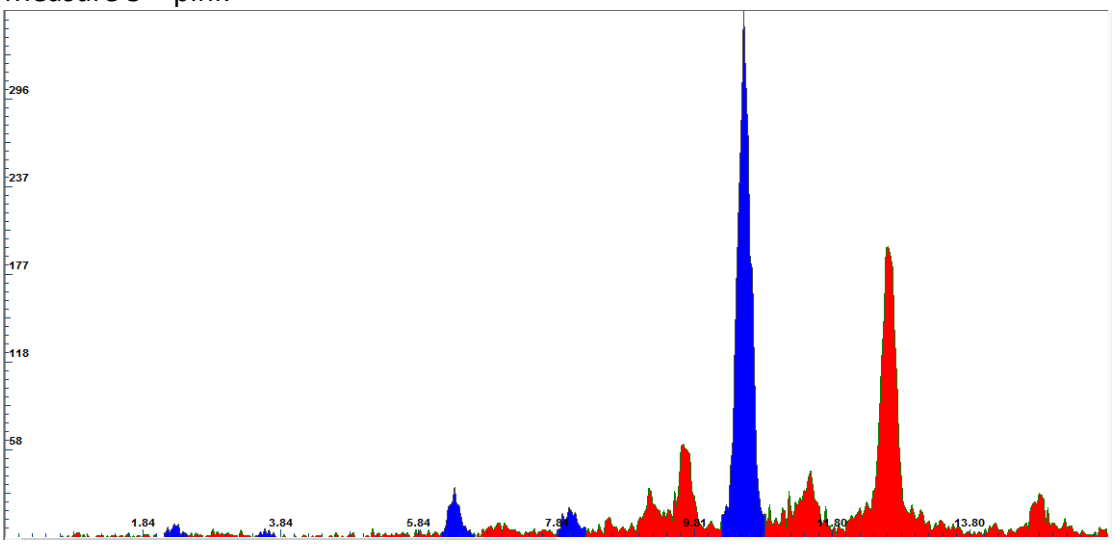
Measure 3 – brown



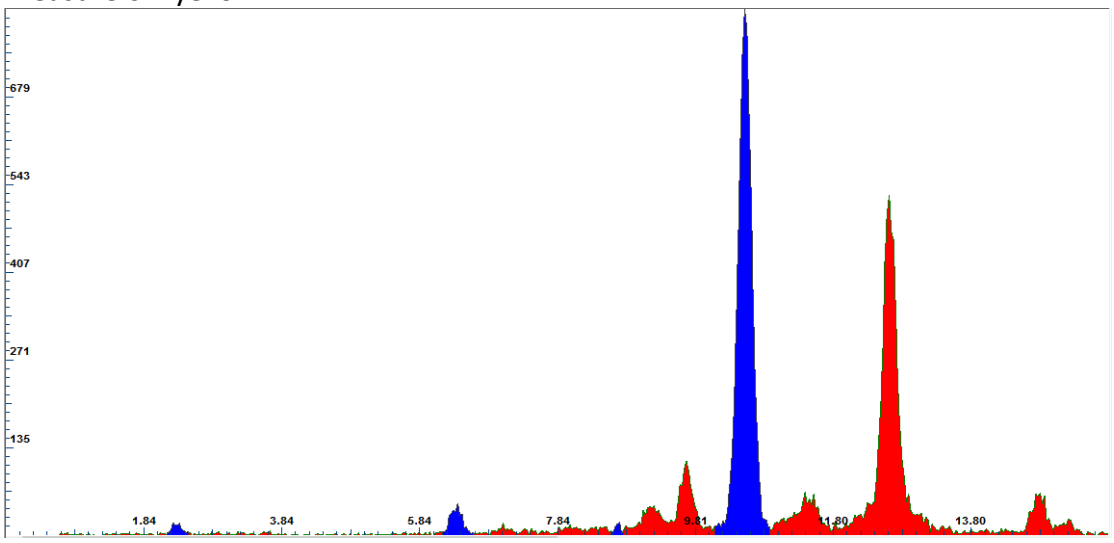
Measure 4 – white



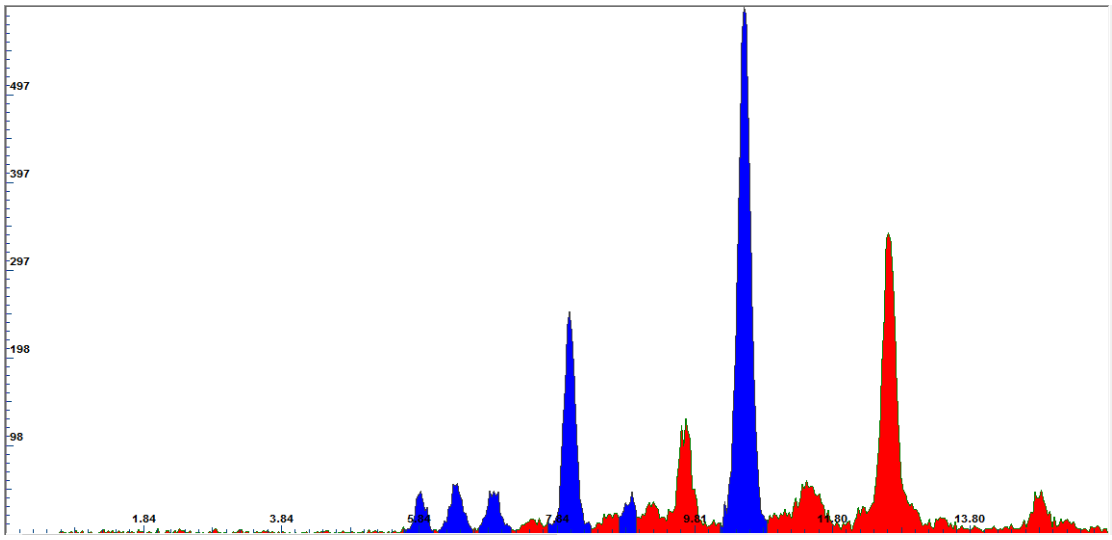
Measure 5 – pink



Measure 6 – yellow

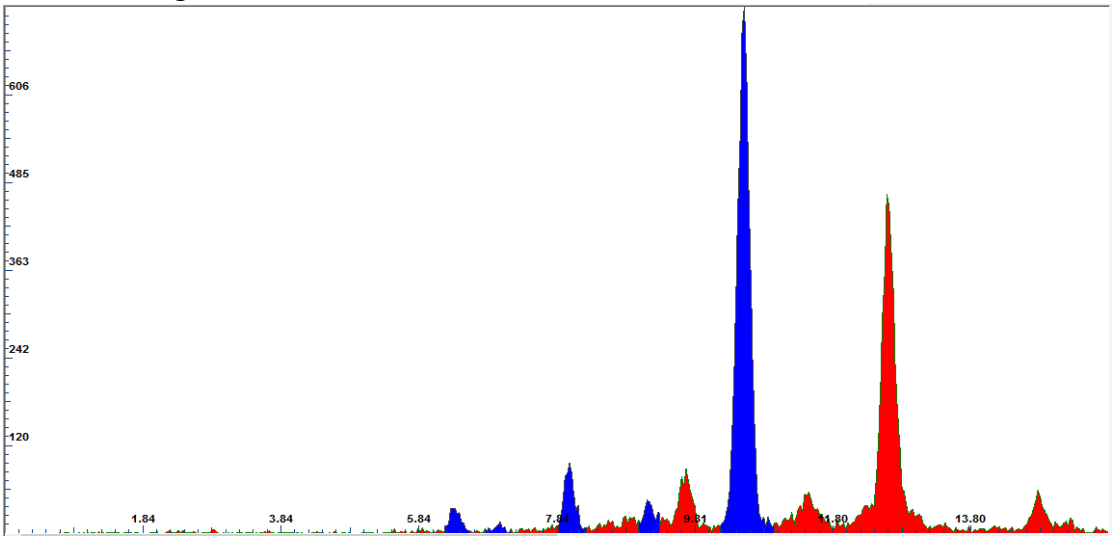


Measure 7 – black

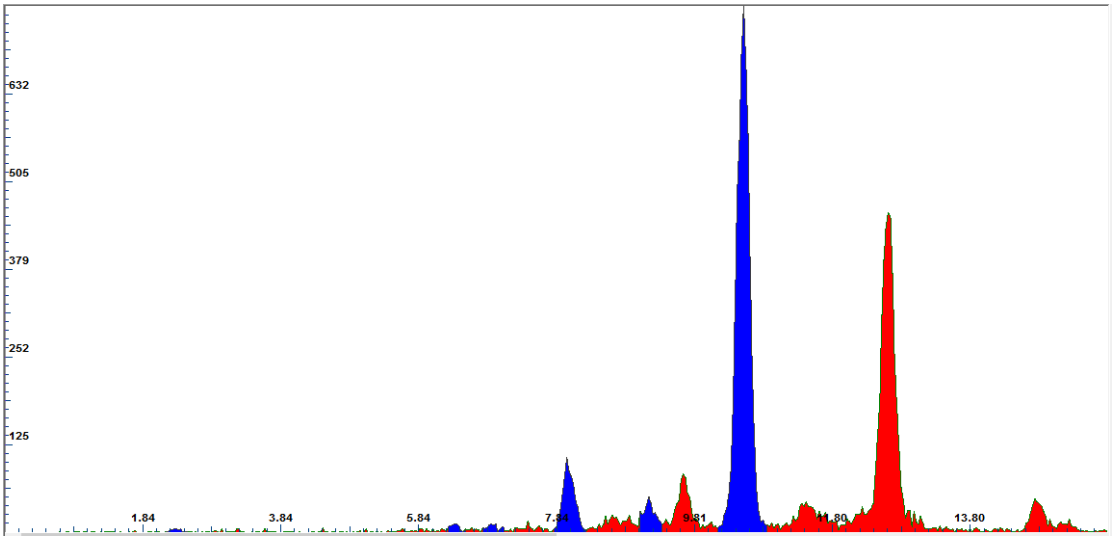


Spectra of EDXRF on Sample 85B

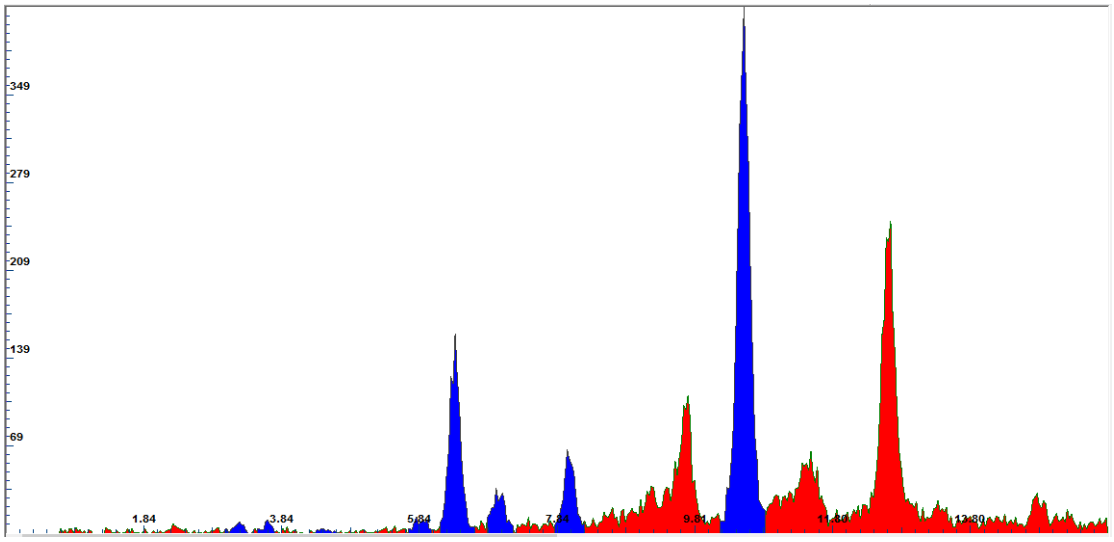
Measure 1 – green



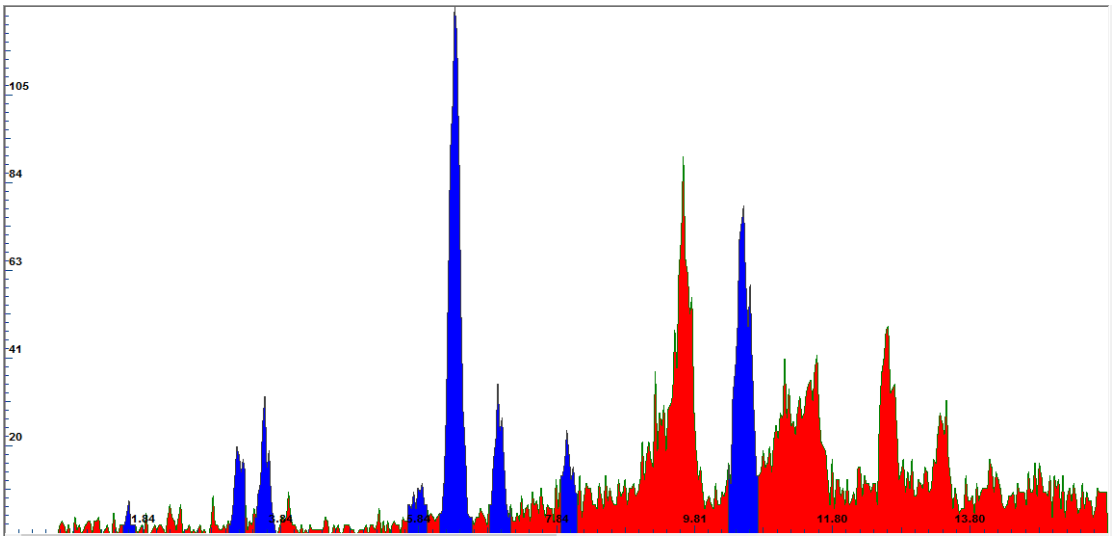
Measure 2 – blue



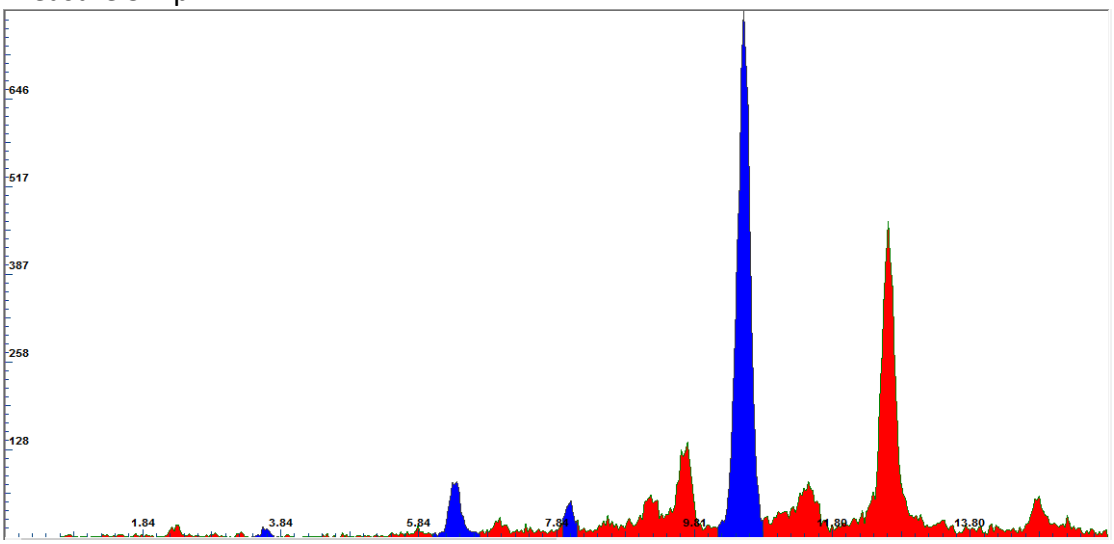
Measure 3 – brown



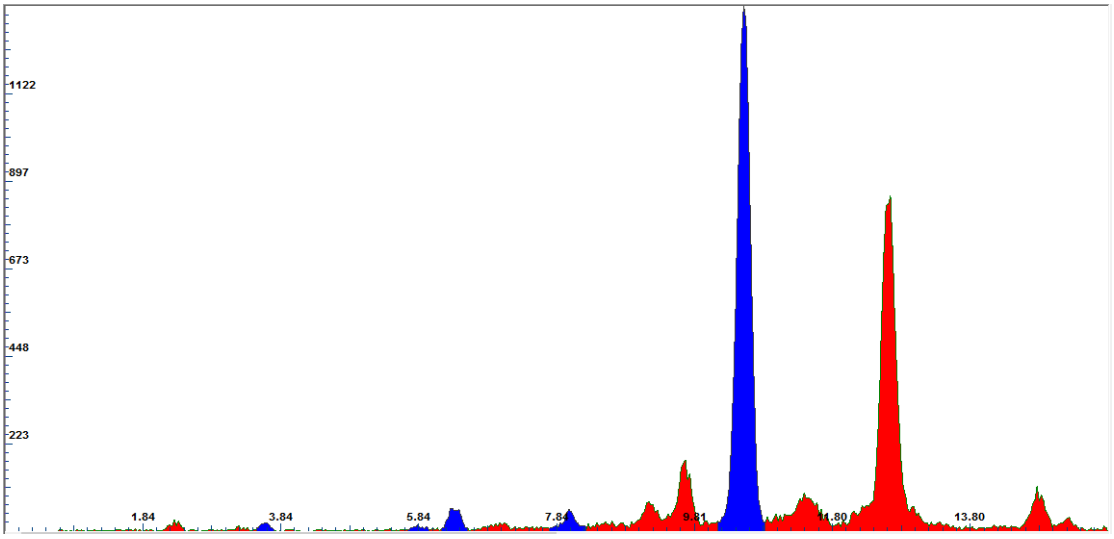
Measure 4 – white



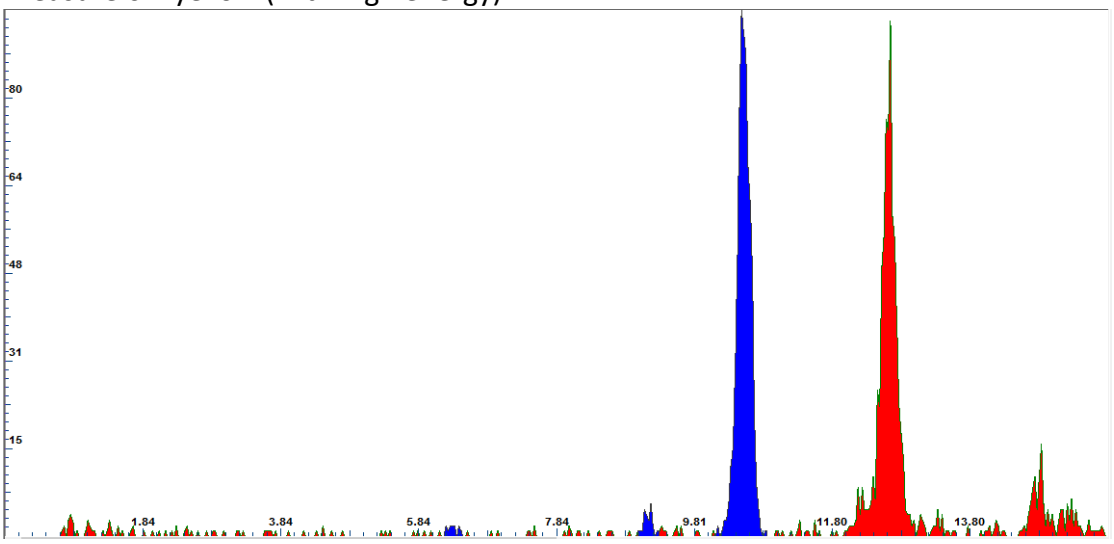
Measure 5 – pink



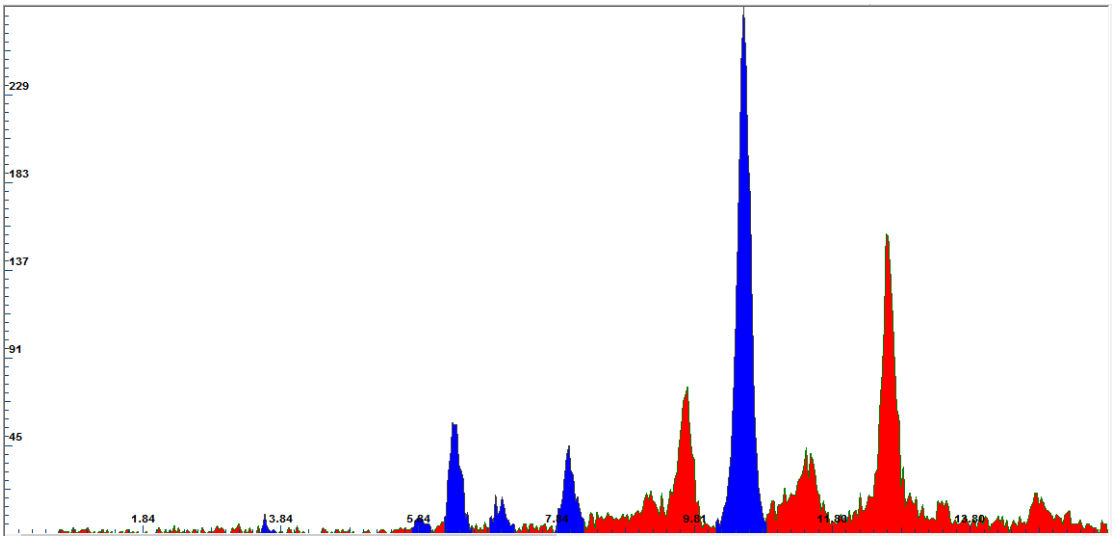
Measure 6 – yellow



Measure 6 – yellow (with high energy)

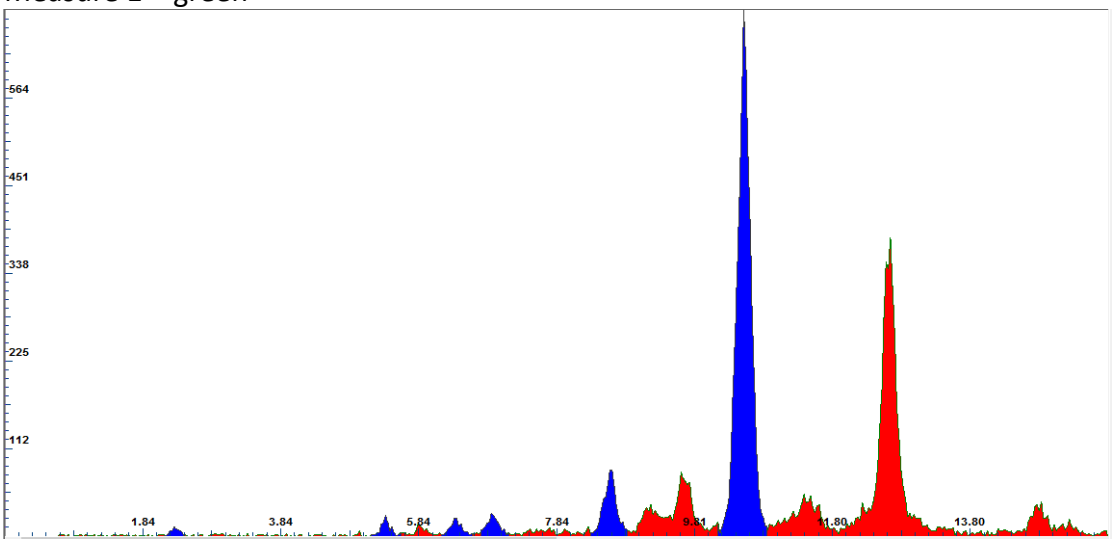


Measure 7 - black

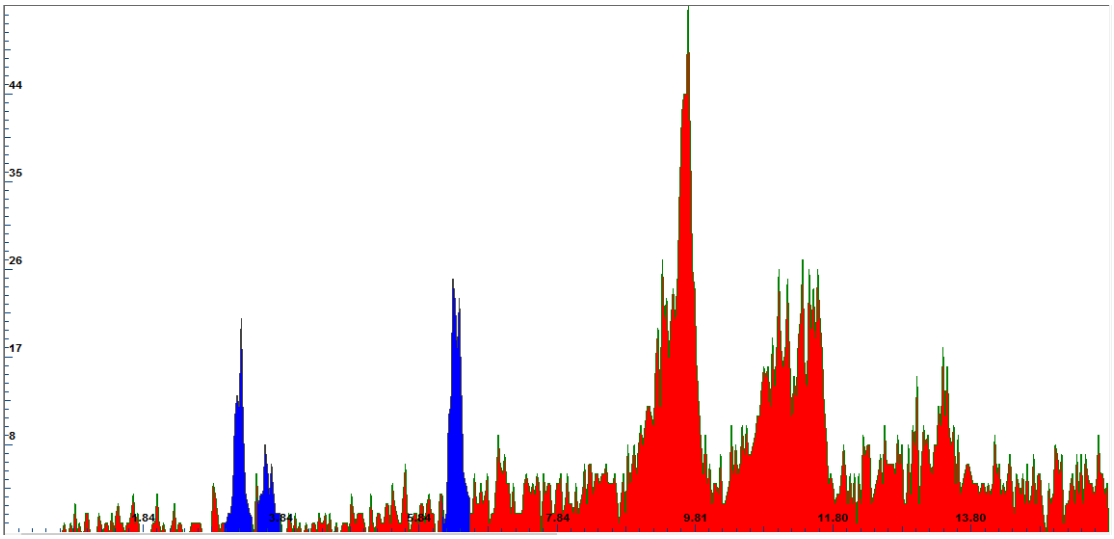


Spectra of EDXRF on Sample 100B

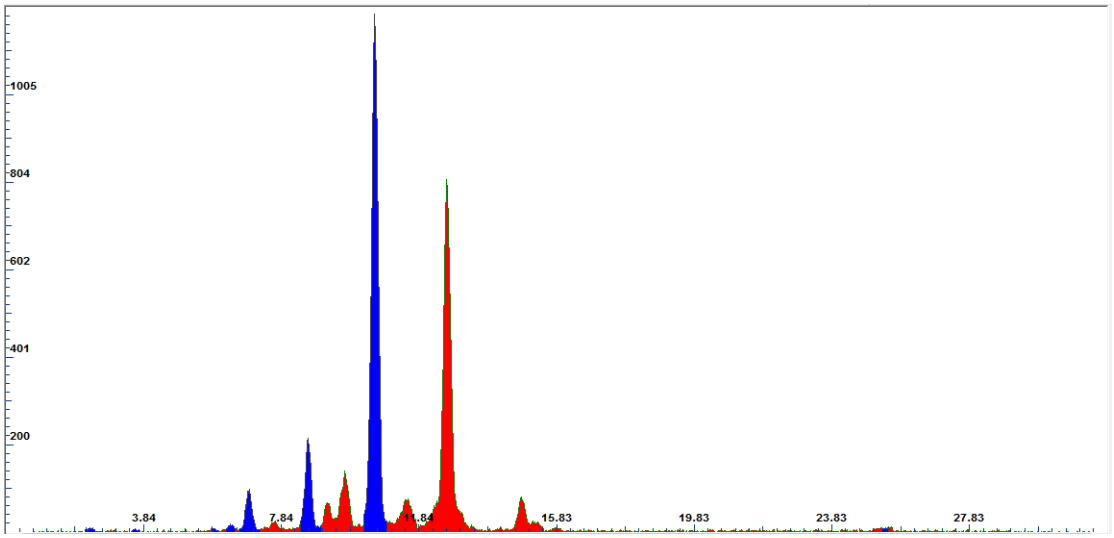
Measure 1 – green



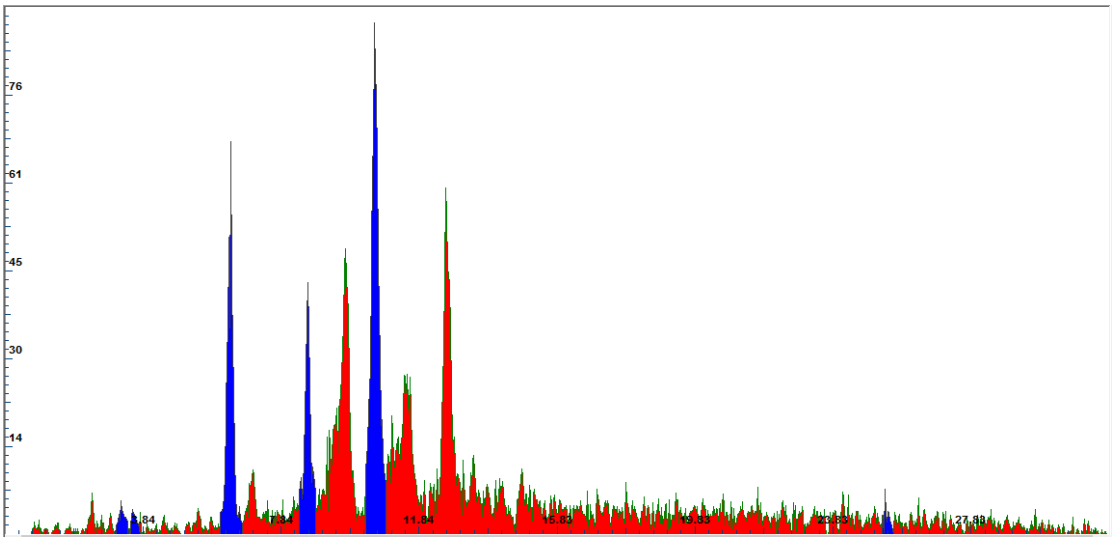
Measure 2 – white



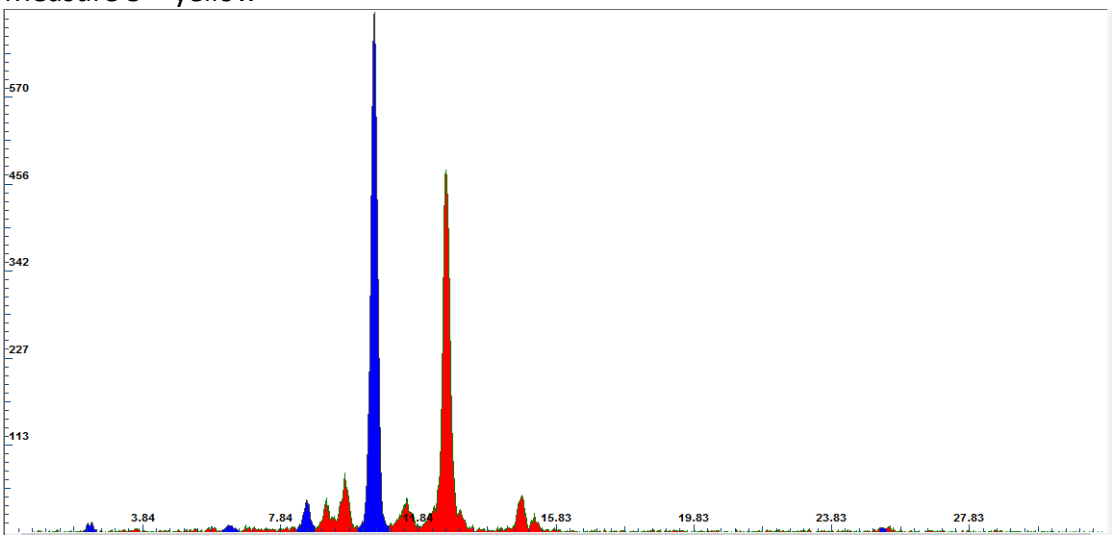
Measure 3 – blue



Measure 4 – red

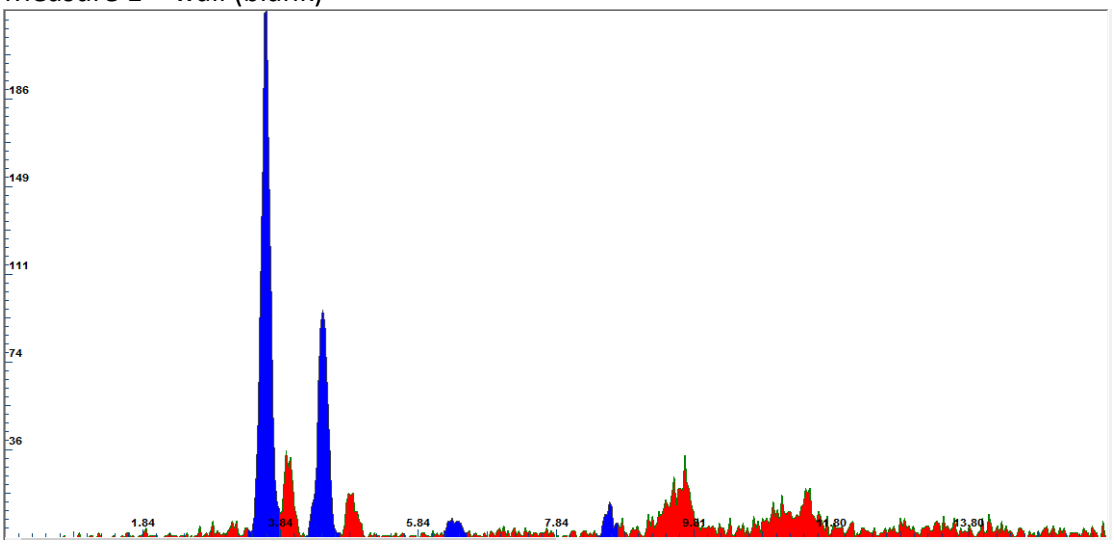


Measure 5 – yellow

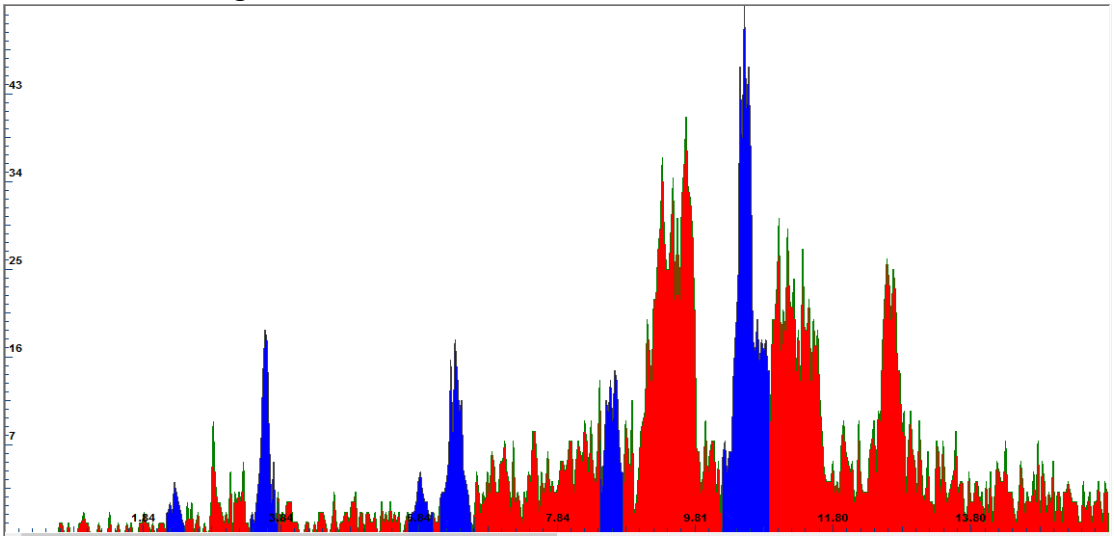


Spectra of EDXRF on Sample 149

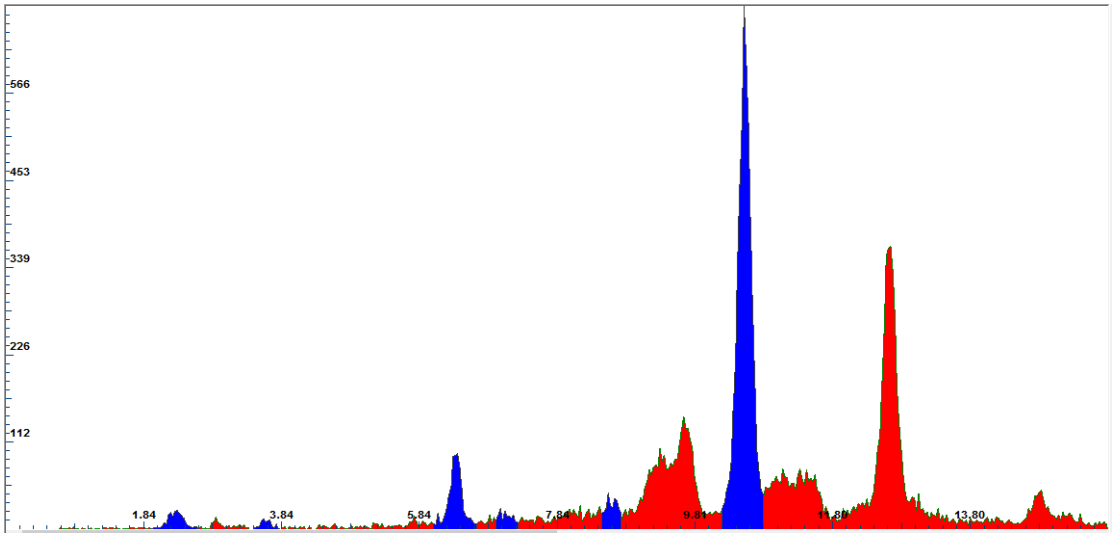
Measure 1 – wall (blank)



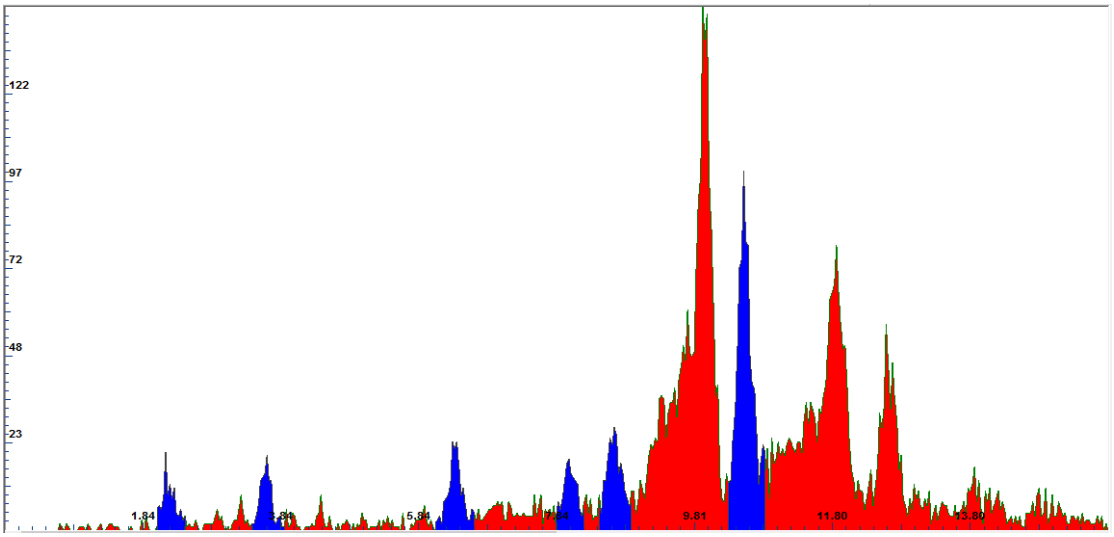
Measure 2 – background



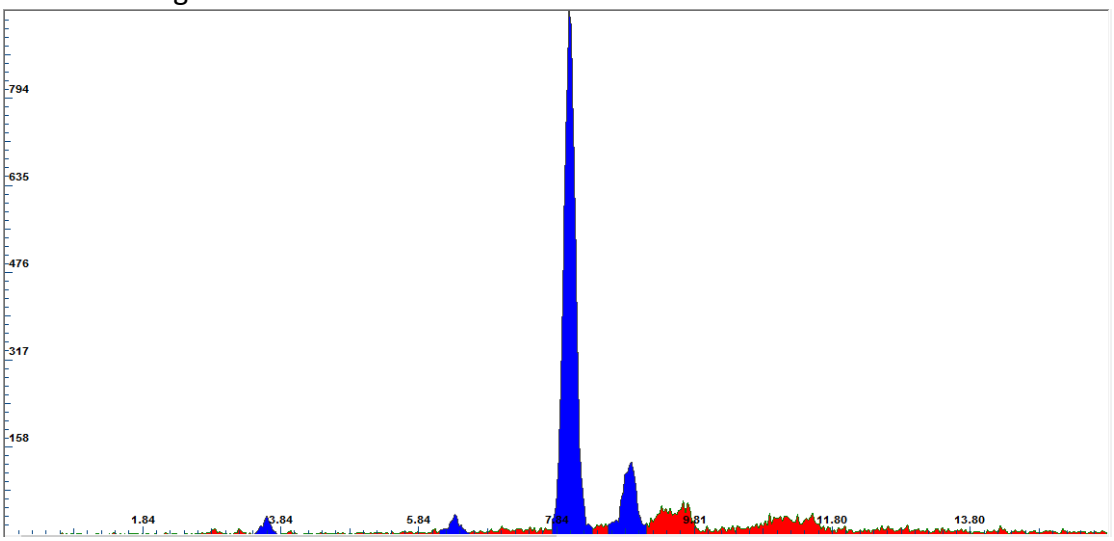
Measure 3 – blue



Measure 4 – red

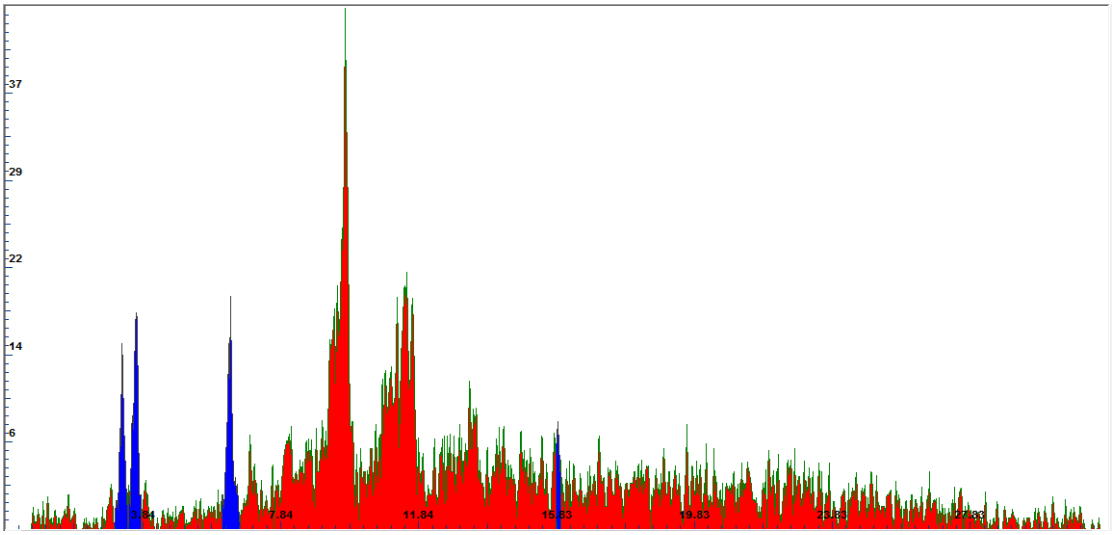


Measure 5 – green

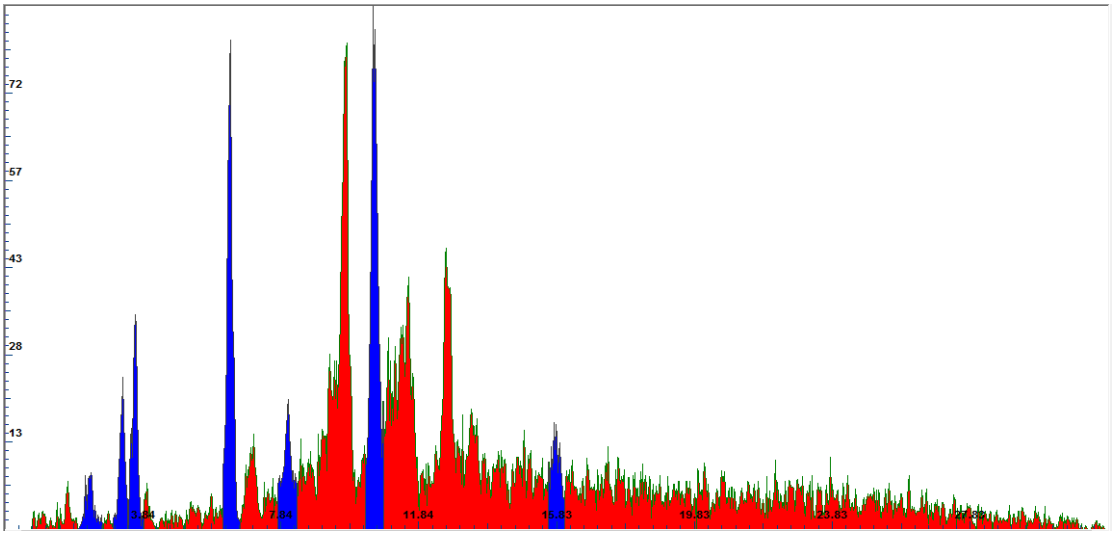


Spectra of EDXRF on Sample 295

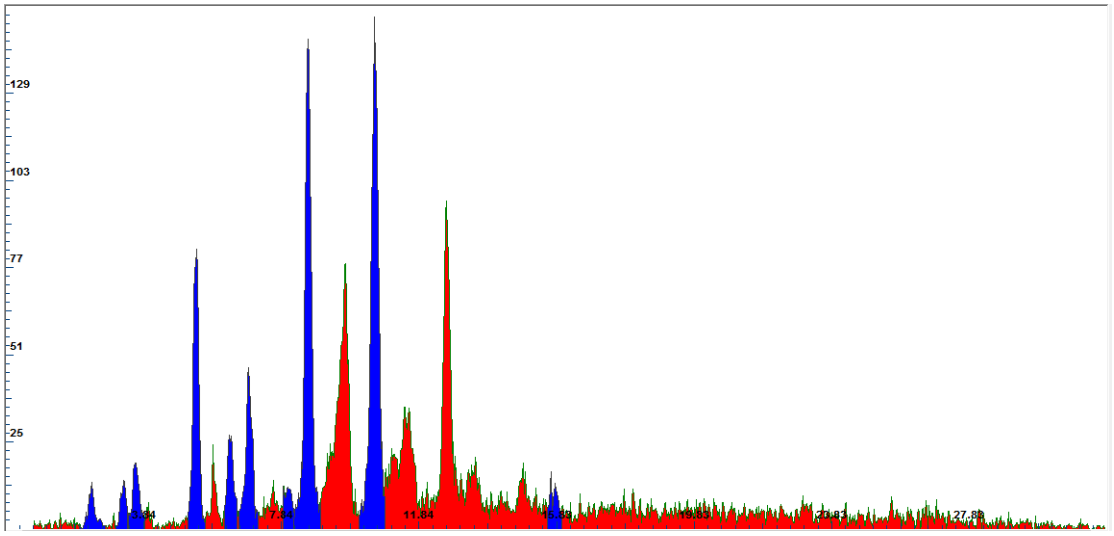
Measure 1 – white



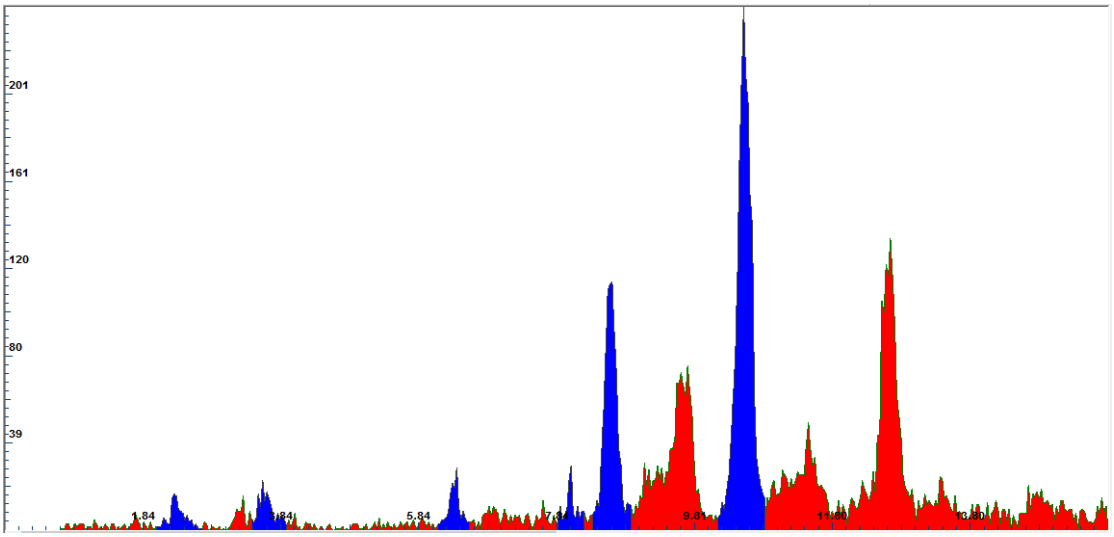
Measure 2 – red



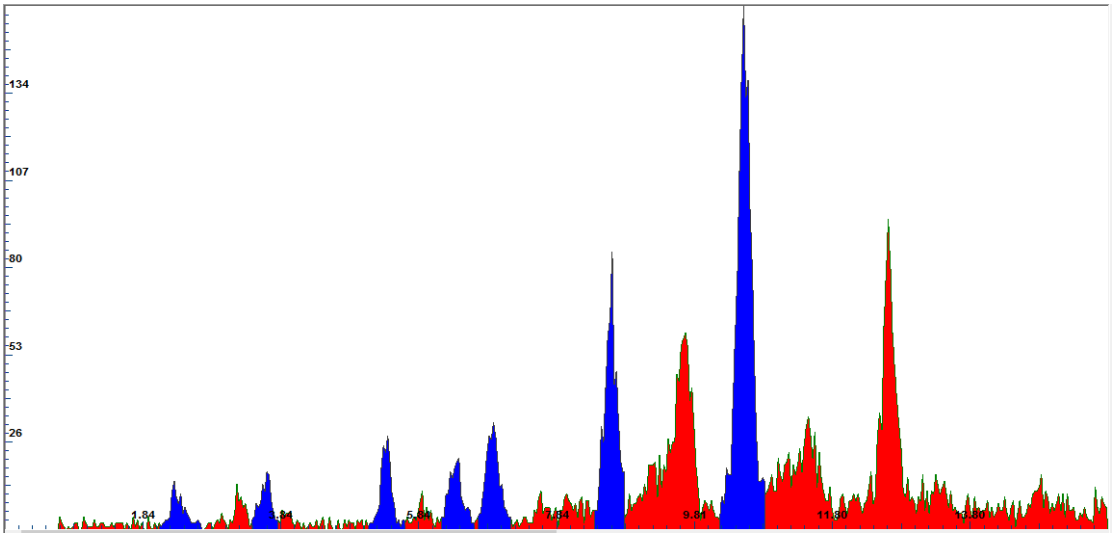
Measure 3 – blue



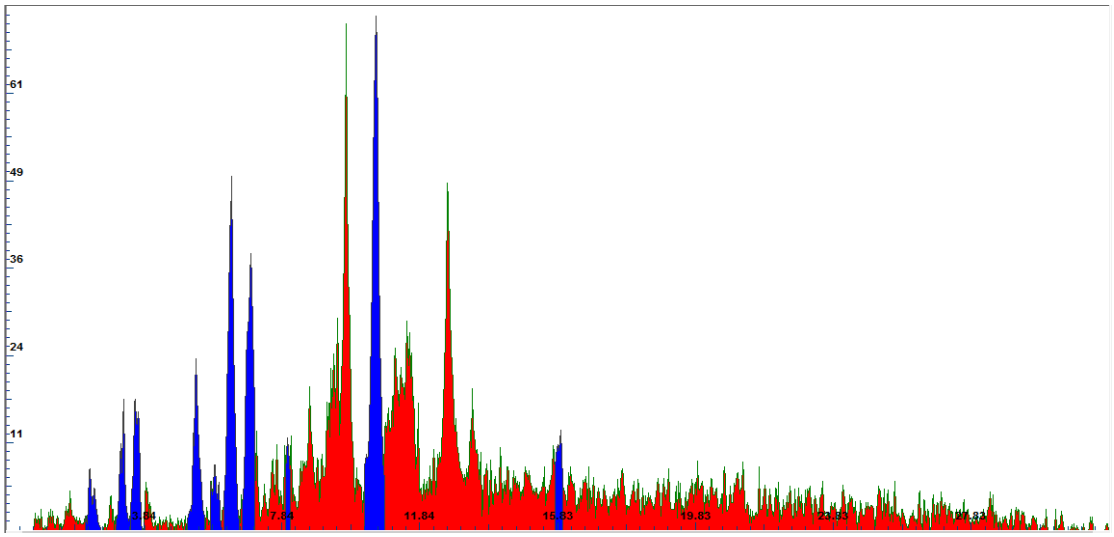
Measure 4 – yellow



Measure 5 – green

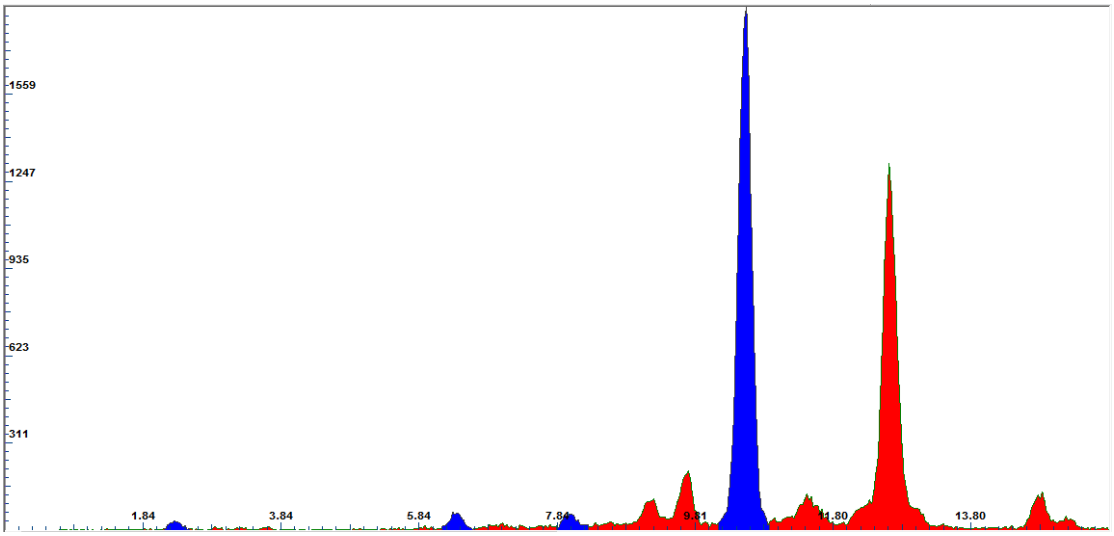


Measure 6 – grey

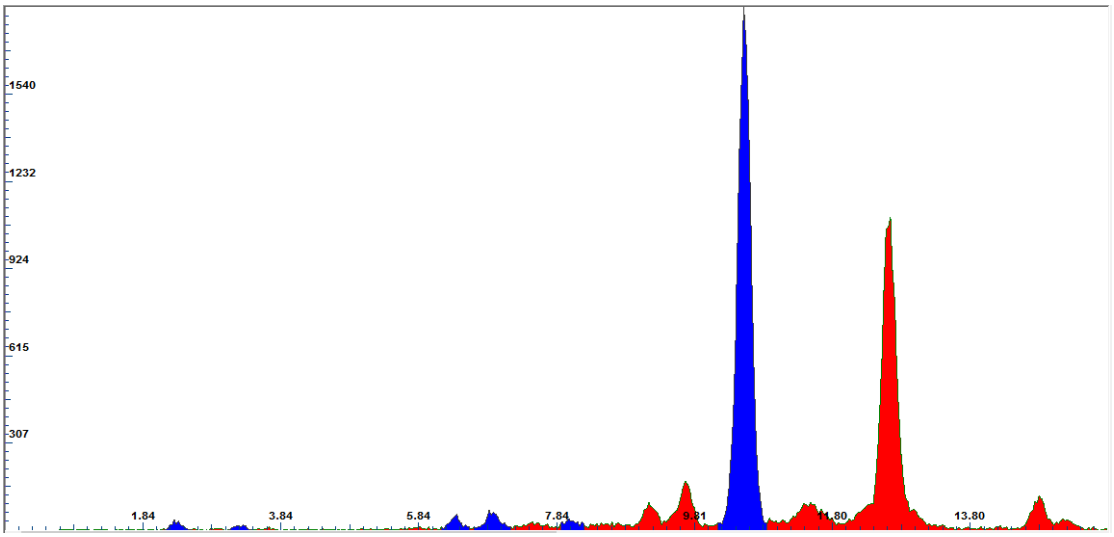


Spectra of EDXRF on Sample 296

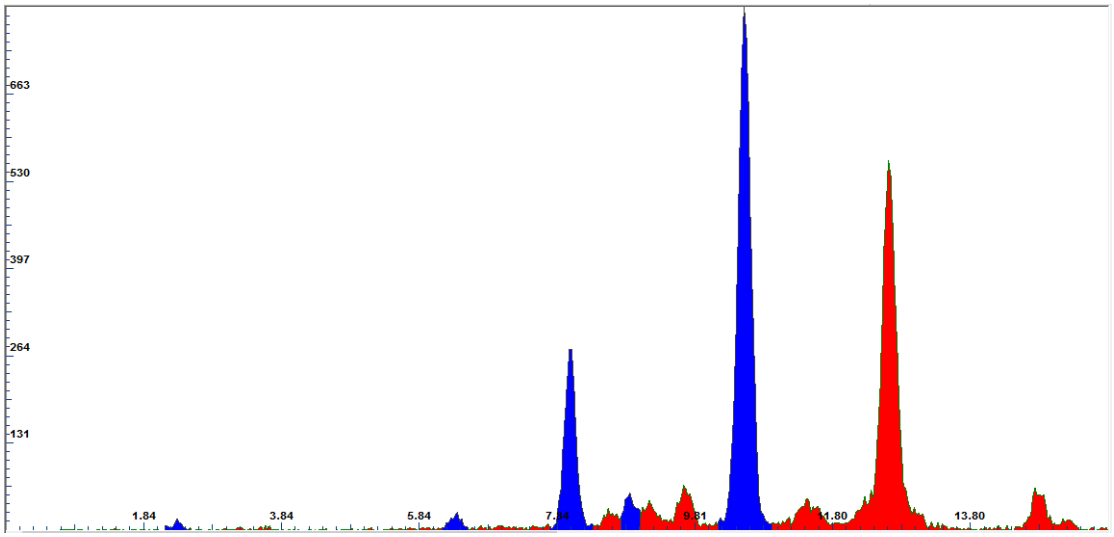
Measure 1 – yellow



Measure 2 – blue



Measure 3 – green



Measure 4 – red