Getting to the Heart of the Matter: The Changing Concepts and Names of Western Chemical Elements in Late Qing Dynasty China

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When modern Western chemistry was introduced into nineteenth-century China, chemical elements were then defined as 'the elementary substances which composed all matters in nature'. For the Chinese, however, significant knowledge already existed regarding chemistry and its elements –including their properties, their preparations, and their compounds. For some time the Chinese had taken the view that an understanding of the elements was a natural first step in the study of chemistry. Moreover, given that the role of the elements in chemistry was so important to the Chinese, their discovery prior to the introduction of Western concepts of matter, helps to illustrate the advances that chemistry had undergone in China from earlier times. Taken together, this historical background is helpful when seeking to distinguish between the development of chemistry in China and in the West. More specifically, it places in better context the assertion that the differences in chemical terms and descriptions between China and the West can be used to explain why Chinese alchemy could not be easily transformed into chemistry.

Even though the earliest translators of chemical textbooks realised the importance of introducing the elements into Chinese chemistry, translation difficulties were not easily solved. This was partly due to the fact that most of the names of elements which were discovered in the West during the mid-nineteenth century had not been translated into Chinese. One of the first challenges to the translator, therefore, was to give the elements a Chinese term. However, no matter what method of expression was used, the names of these new elements were, at first, strange. In fact, many elements were given four or five different Chinese names before 1895. Moreover, given that the Chinese interpreted the nature of these elements based on Chinese natural philosophy, the influence of these names was hard to estimate. Nevertheless, any language limitations could have been overcome if experiments had also been conducted. However, if there was a flaw in the

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Chinese scientific method, it was in its lack of practical experimentation and observation –instead preferring to study and research through the reading of books. Thus, although the Chinese studied the nature of the elements, they neglected the importance of quantitative detail, which is the basis of good chemistry.

The introduction of chemistry into nineteenth century China

There were three main channels for the introduction of modern Western chemistry into nineteenth-century China, namely, through medical missionaries, Tongwen College, and the Jiangnan Arsenal.[1]

In 1855 Benjamin Hobson (1816-1873), an English medical missionary, made mention in his influential book –*Bowu Xinbian* (New Treatise on Natural Philosophy and Natural History)– of 56 elements found in nature. In the book he also briefly introduced the properties and preparation of oxygen, hydrogen and nitrogen. This has long been considered to be the beginning of the introduction of modern chemistry into China. Along with these developments, 17^{th} century Jesuit missionaries, keen to influence Chinese belief in their Christian God, decided to replace astronomy with medicine as the chief means through which to proselytise.[2] They reasoned that, in the training of medical practitioners, knowledge of chemistry was considered a basic requirement.

In 1870, John Kerr (1824-1901), an American missionary, and Liaoran He collaborated to publish a textbook of chemistry –*Huaxue Chujie* (Elements of Chemistry)– which proved to be one of most significant publications on chemistry during this period. Liaoran He, a Chinese scholar, learned Western medicine from Hobson during the 1850's; while Kerr, the founder of the Chinese Medical Missionary Association established in 1887, played an important role in introducing Western medicine and chemistry into late Qing-dynasty China.

A second path for the introduction of chemistry into China came through the Tongwen College. In order to train translators the Qing government, after a series of military defeats, established Tongwen College in 1862, the earliest modern government school in China. After intense arguments with Chinese high officials, Tongwen College students began, in 1867, to learn Western natural science. One year later, William Alexander Parsons Martin (1827-1916), an American Presbyterian missionary, published the first textbook on natural philosophy in Chinese –*Gewu Rumen* (Elements of Natural Philosophy and Chemistry). This book contained seven volumes; the first five volumes dealing with natural philosophy, the sixth with chemistry, and the seventh with mathematics. The sixth volume of *Natural Philosophy* was later republished as *Jiaohui Xinbao* (The News of the Churches) in 1869 under the title *Huaxue Rumen* (Introduction to Chemistry) –and is the version used in the current study. In 1873, Anatole Billequin (1837-1894), a chemistry teacher from France working at Tongwen College, also published a textbook on chemistry for their students.

The third channel for the introduction of modern Western chemistry into late Qing China came through the influential organisation known as the Jingnan Arsenal.[3] The department of translation at Jiangnan Arsenal was founded in 1867, and in 1871 the department published its *Huaxue Jianyuan* (Mirror of Chemical Science) –which was translated by John Fryer (1839-1928) and Xu Shou (1818-1884). *Mirror of Chemical Science* became the most influential chemistry textbook in nineteenth century China.[4] Both Fryer and Xu cooperated to translate many other works on chemistry and related subjects: including *Huaxue Jianyuan Xubian* (Continuation of Mirror of Chemical Science, 1875); *Huaxue Jianyuan Bubian* (Supplement to Mirror of Chemical Science, 1880); *Huaxue Kaozhi* (Qualitative Chemical Analysis, 1883); and, *Huaxue Qioushu* (Quantitative Chemical Analysis, 1883).[5]

Interestingly, the original versions of "*Continuation of Mirror"* and "*Supplement to Mirror"* were based on Bloxam's work on inorganic and organic chemistry –see *Bloxam's Chemistry: Inorganic and Organic, with Experiments and a Comparison of Equivalent and Molecular Formulas* (London: John Churchill and Sons, 1867)– and were to become the first and most meaningful textbooks on organic chemistry in nineteenth-century China. Moreover, *Bloxam's Chemistry* became the basis for *Huaxue Cailiao Zhongxi Mingmubiao* (*A Chinese-English Vocabulary of the Names of Chemical Substances*). This book, the first dictionary on chemical substances, was published in 1885 by the Jiangnan Arsenal. Following the translation of *Bloxam's Chemistry*, no other textbooks dealing with organic and inorganic chemistry were more advanced or abundant than this book, at least before 1895.[6] *Huaxue Kaozhi* and *Huaxue Qioushu* which were translated from the *Manual of Qualitative Chemical Analysis* (New York: John Wiley, 1875) and *Quantitative Chemical Analysis* (London: John Churchill, 1876) of Karl R. Fresenius (1818-1897) are respectively the first Chinese publications on qualitative and quantative chemical analysis.[7]

Thus the *Mirror of Chemical Science*, although nothing more than a book of elements, nonetheless became the most influential publication on chemistry during the late Qing-dynasty. On the other hand, as to the original works, no publications had more influence than *Wells' Principle* and *Bloxam's Chemistry*. Wells made use of the arrangements, classification of subjects, and illustrations, from the works of Faraday, Miller, Graham, Regault and Hayes. For example, utilising Miller's *Elements of Chemistry* (Part I-III, New York: J. Wiley, 1871-74), and Graham's *Elements of Inorganic Chemistry* (Philadelphia: Blanchard and Lea, 1858), Wells began by devoting four chapters to matters of physics, covering 155 pages. The remainder of the book devoted eleven chapters to inorganic chemistry, and ten chapters to organic chemistry. The great general principles of chemistry, and the more important properties of the elements and their compounds, were, accordingly, very fully discussed. On the other hand, the custom adopted by many other text-books of enumerating and describing compounds which have little or no practical value or scientific interest, was disregarded.[8]

Alongside the work of Wells, *Bloxam's Chemistry* consisted of 453 paragraphs, headed by a topic title, covering 676 pages. Part I, the introduction, contained only three paragraphs; Part II, dealing with the chemistry of the non-metallic elements, had 179 paragraphs; and, Part III, dealing with metallic elements, comprised paragraphs 183-323. The last part dealt with organic chemistry.

Translation(s) for the term "element"

Aristotle's four-element concept was introduced by the Jesuits into China at the beginning of the sixteenth-century.[9] The term 'element' was first translated as *yuanxing* (primary phase), under the influence of the term *wuxing* (five phase) –which contained metal, wood, water, fire and earth. In *Qiankun Tiyi* (On the Structure of Heaven and Earth), published by the Jesuit Matteo Ricci (1552-1610) in 1608, the term element was defined as 'a substance that is pure'.[10]

During the nineteenth century there came to be two translations in use for the term 'element'; one was *yuanzhi* (primary substance), and the other was *yuanzhi* (original substance). Although the sound of the two *yuan* is the same, their characters are different. The former was translated by Hobson in his *New Treatise,* and the latter was used by Martin, Kerr, Fryer and Billequin. However, the term for element used by the Chinese today –*yuansu* (primary substance)– is a Japanese-Chinese combined character, introduced at the beginning of the twentieth century.

The number of elements

Prior to 1895, 65 elements had been introduced into Chinese chemistry. However, before 1875, the introduction of *Mirror* said that there were only 64 elements in nature. The 65th element, gallium, discovered by the French chemist using spectroscopy in 1875, was only introduced at the back of the *Supplement to Mirror of Chemical Science.*[11]

Prior to this, Hobson's *New Treatise* mentioned that 56 elements had been discovered in the world. However, Hobson only briefly introduced four elements –namely oxygen, hydrogen, nitrogen and carbon. In his *Introduction to Chemistry*, Martin mentioned that 62 elements had been discovered, but only 42 elements were listed –and only 25 of these were named in Chinese. In Kerr's *Elements of Chemistry*, he stated that 65 elements had been analysed in chemistry. However, Kerr only listed 63 elements that had been translated into Chinese. The four elements, cesium, rubidium, thallium and indium, discovered during 1860 to 1863, were named in *Elements of Chemistry*, but not introduced in the text.[12] Their discoveries, and the meaning of their names and their properties, were first described in Fryer's *Mirror*.

In 1858 *Wells's Principles* listed 62 elements, with pelopium and ilmenium wrongly mistaken as elements. Some other non-English named elements - for instance, stibium (antimony), natrium (sodium), kalium (potassium), wolfram (tungsten) - were also listed in his table. However, it is clear that the four elements - cesium, rubidium, thallium and indium –which were on the elements list in Fryer's *Mirror*, were not listed in *Wells's Principles*. They were noted from *Bloxam's Chemistry*. Moreover, like most other textbooks, the elements were listed by chemical name in *Wells's Principles;* whereas the elements in *Bloxam's Chemistry* were classified by their chemical properties: non-metallic and metal elements.[13]

Supplement of Mirror, a translation of inorganic chemistry, was more readily available and more advanced in chemistry than *Mirror*, and this was the only publication which introduced the element gallium into nineteenth-century China. So why didn't *Supplement* became as popular as *Mirror*? One of the reasons is probably that it was more difficult to understand and because there were only a few chemists in China who could explain the content in Chinese.

When the Chinese began to study modern Western chemistry in the nineteenth century, the introduction of the history of science was definitely helpful for them. Wells' *Principles* and Bloxam's *Chemistry* both had the same characteristic, namely that the histories of the elements were also mentioned, including the meanings of terms and their discoveries. But Wells paid greater attention to the history of science than was heretofore customary in elementary text-books. He did this primarily to enable students to understand more clearly that chemistry relates to the past and present progress of civilisation, and to the industrial operations of the age. What the Chinese thought of the discovery of the element was, in some respects, an essay on the progress of civilisation. In the late Qing-dynasty China, Westerners were still considered as barbarians. Thus the scientific progress of the West, particularly as it related to chemistry, was beyond the imagination of most Chinese. Moreover, when the Chinese studied Western mathematics, introduced by the Jesuits during the late Ming dynasty, they came to the view that Western study had originated in China.[14] This view was to persist well into the late Qing period.

Translation difficulties

The task of translating the names of about 50 new elements into Chinese was probably the first thorny problem facing the introduction of modern chemistry into China. Elements such as *jin* (gold), *yin* (silver), *tong* (copper), *tie* (iron), *xi* (tin), *qian* (lead), *gong* (mercury), *tan* (carbon) and *liu* (sulphur), were already well known in ancient China, so these names were kept in the list of elements.

In 1849 Hobson first introduced oxygen and nitrogen air in his *Tianwen lyuelun* (A Digest of Astronomy). Oxygen air was named *yangqi* (nurturing gas) because due to its obvious ability to sustain life. Yet, if there was too much oxygen in the atmosphere, it was instead destructive to life. Thus the role of nitrogen was seen as being able to harmonise oxygen, making it more suitable for all life-forms. Nitrogen, therefore, was called *danqi* (diluting gas).[15] In 1855, Hobson added the role of hydrogen air in his *New Treatise*. He named hydrogen as *qingqi* (light gas), referring to its property of being the lightest of the chemical element.[16] Hobson's translation of *yang* (nurturing, oxygen) and *qing* (light, hydrogen) was accepted by all translators before 1895. Moreover, his translation of *danqi* (diluting, nitrogen) was also accepted by Kerr and Fryer. Interestingly, Hobson's translation of *yang* (oxygen), *qing* (hydrogen) and *dan* (nitrogen) are still in use today.[17]

Starting from this base, translators began to give Chinese names to new elements by either referring to existing terms, or by using the meanings or pronunciation of Western terms and their chemical properties. Martin, Wilhelm Lobscheid (1822-1890), Kerr, Fryer, Daniel Jerome MacGowan (1814-1893), and Billequin, all used different principles for translating the names of new elements during this period. As a result, some elements had as many as six different names in Chinese. In attempting to overcome these translation difficulties, the most significant rule for translating elements was that used by Fryer and Xu in *Mirror of Chemical Science*, namely that each element be assigned by a radical-syllable coined character.

Martin named some new elements by translating their meanings –for instance, *guangyao* (light medicine) for phosphorus, *shijing* (stone essence) for calcium. He also used existing names for already discovered elements in China –for example, *xinshi* (arsenic); *mengshi* (manganese). Specifically, he used the character *jing* (essence), which is the second character in the name –for instance, *fanjing* (alum essence) for aluminum, and *pojing* (glass essence) for silicon. His names for elements, therefore, should have been easily accepted by the Chinese, given that he coined no new characters and used only the existing names. However, only 39 elements were termed by Martin.

Almost in the same year, Wilhelm Lobscheid, a Germany missionary, used the character *xing* as a basis for coining 22 new elements. He did this by inserting a character, which was usually the meaning of the Western term, or the chemical properties of the element, in the middle of *xing* (element) – for example: bromine, carbon, chlorine, fluorine, hydrogen, iodine, nitrogen, oxygen, phosphorus, potassium, selenium, silicon, sodium, strontium, tellurium, thorium, titanium, tungsten, uranium, vanadium, yttrium, zirconium.[18]

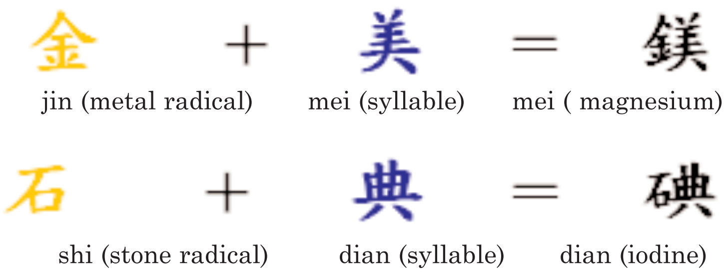
The formation of Lobscheid's character

xing (element) *tian* (heaven) *tian* (uranium)

Lobscheid was the first to present new elements through a single coined character. However, while Lobscheid's combination character may have had an impact on Fryer's translation principles for elements, his characters showed a definite relationship to MacGowan's terms. In 1872 Daniel Jerome MacGowan and Hengfang Hua (1833-1902) transcribed the English sounds of the elements in their *Jinshi Shibie* (Discrimination of Mineral). Barium, for instance, was *bei-er-yi-en*; calcium, *gai-er-x-ien*; magnesium, *mei-he-ni-xien*. These first characters were applied to combine with a metal radical to form characters by Fryer and Xu. MacGowan was an American Baptist missionary and a translator. Hua was well known as a mathematician as well as a translator. Although *Discrimination of Mineral* was published in 1872, its chemical terms were already translated by 1868.[19] Its original version was the *Manual of Mineralogy by* Dwight Dana (1813-1895).

Before the publication of *Mirror of Chemical Science*, Fryer's translation of the names of the elements had already influenced another translator. In 1869, Fryer sent his names of elements to Kerr for his opinion and comment. In turn, Kerr applied Fryer's ideas for the translation of elements in his *Elements of Chemistry*.[20]

Fryer-Xu's radical-syllable combination



Out of the 65 elements, Fryer and Xu used nine traditional names and four from other translators. Of the remaining 52 only two were translations: one being *chou*, which means stink with water radical for bromine; and the other being *bo*, which mean white with metal radical for platinum. The names of the other 48 elements were assigned by a radical-syllable character. Today, 41 of their translations are still in use.[21]

The Influence of Chinese Natural Philosophy

The concept of elements in ancient China differs from that in Western culture. There were five elements in China –namely, metal, wood, water, fire and earth– which form an interdependent cycle relationship. For example, in the Chinese view, fire brings forth wood, and wood brings forth water. According to the Chinese view of nature, fire represents not only real fire, but also the substances belonging to the character of fire. Chinese philosophers emphasised that everything in nature changes and transforms perpetually. Thus, when the four-element theory was introduced into China by the Jesuits during the late Ming-dynasty (1368-1644), they were understood only through the prism of the Chinese five-phase theory. This situation led to many arguments as Chinese scholars and Jesuits attacked each other with their own concepts and doctrines. During this controversy over five-elements- and four-elements theory, one of the crucial debates to emerge was that over whether or not air was an element. For Chinese philosophers air was not a substance, because it could not be seen and man could not measure its weight. On the other hand, the Jesuits provided several observations and measurements demonstrating that air was really an element.[22]

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In Hobson's *New Treatise*, the concept that air was an element in itself was particularly emphasized:

"Substance, man thinks, is that which he can see, and gas (*qi*) is that which he cannot see. However, there is evidence to believe that gas (*qi*) is substance. In the universe, gas (*qi*) transforms to substance, and substance also transforms to gas (*qi*)."[24]

Zhi or substance, the second character in the Chinese name, not only shows its modern definition, but also indicates the Chinese acceptance of the Western concept. Although the Chinese scholars accepted the definition of element in modern chemistry, they always interpreted the chemical meaning of elements under the influence of such Chinese thinking as natural philosophy. The Chinese translations are definitely one factor to result from such phenomenon. When the Chinese learned the principles of the chemical elements, they always understood them form the meaning of their terms. More importantly, when the Chinese studied Western mathematics, introduced by the Jesuits during the late Ming dynasty, they came to the view that Western study had originated in China.[25] This view was to persist well into the late Qing period. Moreover, the similarity in Chinese and Western natural philosophy promoted the formation of this concept. That, therefore, provided the Chinese scholars with the opportunity to claim that the Chinese classics of natural philosophy correspond to the principles of Western modern chemistry –for example the dualism and yin-yang theories.

Therefore, the elements of gas –such oxygen, nitrogen, hydrogen, fluorine, and chlorine– were regarded by the Chinese as having already been discovered, and were interpreted under the concept of *qi*:

"*Yang* (oxygen) is known as a living gas; *qingqi* (hydrogen air) as a light gas; l*yuqi* (chlorine air) as a yellow-green gas; and *Fuqi* (fluorine air) as a malicious gas. These substances are well known in China as chemical elements. And everyone knows that they are Chinese substances."[26]

The concept of *qi* is one of the oldest and most influential natural philosophies in China. *Qi* is said to be invisible yet present in all substances. Thus *qi*, invisible matter, was used to explain how water, earth, electricity and magnetism could have energy or power in order to cause a change of state. Hence, electricity and magnetism were named as electrical *qi* and magnetic *qi*. Xi Zhu (1130-1200), a Chinese scholar in the Southern Song Dynasty (1127–1279), complemented the theory of *qi* with his principle of *li*. He said that *li* and *qi* were the origin of all living things and that *qi* was derived from *li*. Moreover, *li* was also at the root of the creations of all living beings.[27]

In addition, since the chemical element is defined as the simplest substances from which all living being are composed, the Chinese always connected their properties with the Chinese ancient alchemical achievement. Indeed, the sixty-four elements discovered and mentioned in Fryer's *Mirror*, were regarded by the Chinese as the sixty-four *gua* (trigrams) in the *Yijing* (Book of Changes) The sixty-four trigrams are the total number of combination of trigrams in *Book of Changes*:

"In the early antiquity Fu Xi invented the trigrams. *Yin* and *yang* exchange each other. The firm and the yield displace each other. The foundation of sixty-four trigrams is like that of the sixty-four chemical elements. Shen Nong tested hundreds of herbal medicines, suffered from seventy-two poisons in one day, and was divine in the transformation they wrought. *Bencao Jing* (Classic of Materia Medica) indicated gold, silver, copper and iron smelted by sulfur. Seventy-two stones melted in saltpeter. Sulfuric acid and nitric acid are the evidences. In his book *Suwen Jing* (Classic of Plain Questions), Xuan Yuan wrote that water is yin, fire is yang. Yang is transformed into gas, yin is transformed into solid. The principle of their transformation is the same as that for the transformation between vapor, liquid and solid. It also said that heat makes deconstructive, and blend makes productive that creates all beings. Thus the rulers of the action and creation of substances is clear."[28]

Fu Xi, who is also said to have invented the one hundred Chinese family names, is the first of three noble emperors in Chinese mythology. His successor, Shen

Nung, who is also one of the three, is named as the "God of Herbs." The Classic of Materia Medica which is the earliest Chinese herbal book, wass published before the Western Han-Dynasty (206 BC to 24 AD). However, the author of this book is unknown. Xuan Yuan, the last of the three noble emperors, is considered to be the ancestor of all Han Chinese. Speaking to the change of matters, the Chinese were inevitably disturbed by the Chinese natural philosophy, for example, the influence of the concept of *yin-yang* on the learning of physical changes.

From alchemy to chemistry

As in the West, Chinese alchemy pursued the search for the elixir of life and the transmutation of gold. Western alchemy, however, had transformed into modern chemistry by the end of the eighteenth century. When the Chinese first learned about modern Western chemistry, many students would raise questions in the chemistry class. Questions such as: How did chemistry in the West develop? Or, how did alchemy transform to chemistry in the West? Or, what are the differences in alchemy between China and the West? The discussions that followed these questions were useful to the Chinese in assisting their understanding and learning of modern Western chemistry. Moreover, under Martin's influence, the Chinese began to consider that the discovery of the elements was the single most meaningful distinction between alchemy and chemistry.

As the author of the first textbook on chemistry in China, Martin had an ongoing and sustained interest in Chinese alchemy, believing that Western alchemy had probably itself been brought from China.[29] He was very interested in the questions that the Chinese raised, and himself raised more detailed questions on the comparisons between alchemy and chemistry in the back of his *Introduction to Chemistry*.

At first, Martin compared the differences of the methods in both alchemy and chemistry. He argued that, in ancient times, alchemists sought a good place to build stoves and smelt their base metals in order to feel the 'inspiration of the constellation'. Moreover, in their efforts to manufacture medicine, the alchemists always operated according to the Five Phase principles. However, Martin went on to assert that even if the alchemists had 'eaten the radiance of the moon and taken the red cloud of the morning', they could never have obtained to the essence of matter. So what, then, was the means of chemistry? Martin explained:

"Today's chemists start from an analysis of elements. They resolve not only to understand the different elements, but also to understand the principles lying behind the different combinations of elements. To combine new compounds or to decompose substances, these are the principles of chemistry; and these theories are apparent."[30]

What Martin mentioned above said nothing about the method of analysis or the functions of the equipments used. He probably intended to say that chemical apparatus could be used to resolve more elements. However, although Martin could not indicate the exact means of chemistry, he did reinforce the view that it came about through the discovery of elements and the use of chemical instruments.

Following on from this, Martin spoke about the comparisons of their theories. The alchemist, he said, considered that all metals had the same property. If they could transmute each other, the baser metals could be raised to gold, and the nobler one could be reduced to lead. Alchemists also mentioned that all substances grow as seeds, formed in the earth –much like the combination of sperm and egg. On the other hand, Martin explained that chemistry reduces into more meaningful theories:

"However, the chemist regards that all metals are different. Although they attract each other, they can absolutely not exchange mutual. From lead, silver is extracted, because silver is originally mixed with lead. In cinnabar, mercury is obtained, because cinnabar originally combines with mercury. When the element which is always resolved in the medicine of the manufacture or extracted in the smelting gold, because that this element is at first contained this substance. There is not the so-called mutual exchange of nature."[31]

Finally, Martin shifted to a discussion of the results of alchemy. Many of the mysterious alchemical operations had no the basis in fact, and were merely a desire to acquire more wealth. By contrast, the success of chemistry lay in its application of the analysis of elements, and in medicine. Nevertheless, while Martin compared alchemy and chemistry in their methods, theories, and results, he did not exactly name the alchemists, the chemists, nor the elements in his explanations. Yang Yuhui, meanwhile, a Chinese scholar and a student of Shanghai Polytechnic Institute, has given us a more detailed discussion on this subject:

"It is said in Chinese alchemy that *heche* was water, *zhuque* was fire. That is absurd. It is said that *huangjing* is food, and *baishi* is provision. It is preposterous. The refining of medicine and the analysis of matter in alchemy is the same as in chemistry. Phosphorus in chemistry was discovered by the alchemist Brandt. The more we can improve our chemical research, the clearer will be our understanding of the properties of substances. Phosphorus, for example, was discovered when it burns in the air, giving off a very bright flame, and extremely violent combustion, especially in oxygen air. The element phosphorus was discovered accidentally, so it really should not be regarded as a a success for chemistry. However, the discoveries of other chemical elements does occasionally take place, Iodine, for instance in the form of bluish-black scales, was found by Courtois in the sea-weeds. Bromine, an extremely volatile substance, was occasionally obtained by Ballard from sea-water. These results occurred unexpectedly. The way of chemical success is gradually achieved from rough to perfect. For instance, the research of borax, this substance was found but it's constitution was not clear. It was not until Homberg's experiment that man knew that boron was an element. Soon after, man knew after Gay-Lussac's success that boron was an element. However, man did not still realize the properties of boron. After unceasing investigations mutually, its properties was finally to be understood. The scientific results can not be immediately reached. Chemistry succeeds after alchemy; the understanding of the analysis of elements in alchemy leads to chemistry. Alchemy occurred before chemistry; alchemy is the origin of chemistry."[32]

Heche, zhuque, huangjing and baishi are the obscure symbolic language of the Chinese alchemists. The alchemist, the chemists and the discoveries of the elements which Yang mentioned came from Fryer's *Mirror*.

Returning again to Martin's explanation on the subject, one arrives arrive at the question: How did the Western countries make such rapid developments in chemistry? Martin had asserted that Western governments prohibited the alchemist's attempts to make precious metals in order to prevent swindles. In addition, the activities and organisation of chemistry was encouraged through the arrangement of teachers and the establishment of laboratories in the West. As a result, many students learned chemistry and chose this as a profession. For Martin, this had a great impact on the development of chemistry.[33] However, it was in the area of scientific education that the Chinese struggled initially to realise its function and influence. For them, study should focus on how to govern the country, not on the so-called "arts" or "techniques".

Conclusion

Fryer and Xu were definitely the most significant partners in the introduction of modern chemistry into late Qing China. Their *Mirror* textbook dominated learning about the chemical elements during this period, mainly because it was the first and most detailed textbook, with the introduction of 65 elements. Moreover, Fryer and Xu also paid much attention to the historical development of modern chemistry, and were the first, and only ones, to introduce the five elements cesium, rubidium, thallium, indium and gallium into nineteenth-century China. Nevertheless, despite the earlier influence of Fryer and Xu, it was Wells' *Principles*, although not as advanced and academic as *Mirror*, that became the most influential textbook on chemistry.

Although gallium, the 65th element, was introduced into China via *Supplement to Mirror* (1880), only 64 elements were well known in China before 1895. The naming of the elements in Chinese illustrates the shortcoming of chemical communication in China. As suggested here, one of the reasons was that, as there was no analysis of, or experimental confirmation on, the basic principles of chemistry, the Chinese had difficulty in understanding the subject. And this was to prove a great obstacle to the development of science in China.

At the beginning of the twentieth century, Fryer and Xu's single radical-syllable character principle for the translation of elements finally became the standard for Chinese chemical nomenclature. Such coined radical-syllable characters were so strange and exotic at that time that almost no Chinese had the basic English ability to understand them. But after repeated efforts, and a series of publications, this principle became the most important method for translating the names of new substances in chemistry.

As the Chinese gradually learned of Western scientific knowledge during the late Qing, they always sought to understand and interpret this knowledge through the rationale of Chinese natural philosophy. However, as with the discovery of the elements, the Western study of chemistry could not be interpreted through the natural philosophy of the Chinese due mainly to the concept of Chinese origins of Western science. For example, the mistaken Chinese belief, in the late Qing dynasty, that they had discovered oxygen, nitrogen, hydrogen, fluorine and chlorine long before their discoveries in the West.

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