Why do we read about alchemy and other proto-sciences when they are no more significant after the emergence of modern science, when they are no longer useful for the theoretical as well as applied studies of modern times? Apart from preserving the cultural history of a particular area these studies enable us to understand the origin and development of various branches of science and their interdependence. Further, if the progress in a particular scientific field is studied with respect to social, economic or religious conditions, it reveals the influence of these factors on it. In this way, studies in history of science and technology are not only of historical interest but they also contribute in determining the future course of scientific research by moulding the influencing factors suitably.

A study of alchemy and other chemical practices reveals the way chemical experience was accumulated through ages and the way it later became the basis of the modern science of chemistry. The ancient theories which regarded matter to be consisting of basic four or five elements such as earth, water, fire, air and aether, with their
combinations, were insufficient to explain all chemical phenomena, e.g., transformations occurring in nature and those occurring in metallurgical and alchemical operations. Consequently, these theories were abandoned and scientists of the late medieval period put forth new theories trying to explain their observations. These new theories, which were verified by experimental methods, paved the way to new ideas regarding matter, elements, chemical combinations, chemical compounds, etc., finally giving rise to the modern ideas of chemistry.

Modern atomic theory proves that alchemists' attempts of transmuting base metals into gold and silver were doomed to fail. It pointed out that transmutation or transforming one metal into another is only possible if the nucleus of that element is converted into the nucleus of the other element, with the requisite number of protons and extra-nuclear electrons. This happens naturally in the case of radioactive elements. To bring about this kind of transformation artificially a nuclear reactor is necessary. The energy changes involved are so tremendous that they are impossible by the older methods. The only source of energy in those times was heat. The energy supplied by heating the ingredients together is insufficient and negligible compared to energy changes required in actual transmutation of elements.
Thus we know that the medieval alchemists were engaged in an endeavour in which they were never to succeed. Yet during their long labour they did discover a number of chemicals, methods and techniques, gathered vast chemical knowledge which when viewed in the proper perspective provided basic data for the further progress in the field of chemistry.

While studying alchemy and protochemistry we propose to find what is the chemical explanation of these experiments and what discoveries were made in that course, probably the alchemists themselves being unaware of it. A thorough study of alchemy and also of comparative alchemies will tell us how far alchemy was a pre-chemistry, whether chemistry emerged as a theoretical development of certain main areas of earlier practices or if it altogether abandoned them and emerged as an entirely new area of study. In short it will enable us to understand the way transition from alchemy to modern chemistry occurred in the seventeenth to eighteenth centuries.

Alchemy and Its Origin

The term alchemy is primarily applied to the earlier practices of gold-making and synthesizing "elixirs of life". The roots of alchemy lie in two greatest desires of man; the first being acquiring wealth to enable him to
enjoy the earthly pleasures, and the second being escaping death. Evidences of alchemical practice are found in all the early civilizations. Origin of the word "alchemy" is suggested in the Greek word "Chemia" which was used to denote the arts of making gold and silver from base-metals. Its Arabian modification "al-chemia" finally led to the word alchemy, which came into existence in the English language.

The Sanskrit equivalent of alchemy is "Rasāyanasāstra". "Rasa" means a fluid or body-fluid and "Āyana" is "arrival". "Rasāyana" thus means a substance which increases the body fluid or vitality. The term "Rasāyana" was commonly used for mercury elixirs and consequently "Rasāyanasāstra" or "Rasasāstra" for the science of making elixirs of mercury. Probably due to its shining silvery appearance and its easy transformation to cinnabar (mercuric sulphide) which is a bright red compound, the ancients conceived the idea of mercury being potent. Moreover, mercury forms amalgams with other metals readily. Most of the mercury amalgams are silvery white and that with silver is golden-coloured. This property of mercury made the early alchemists believe that it was capable of transforming other metals into gold and silver.
The Medieval Alchemist and His Endeavours

The chief endeavour of the medieval alchemist was to synthesize an elixir which would change base metals like iron, lead, tin or copper into gold and silver, and also which would be effective when taken internally for achieving longevity and immortality. A large number of alchemical texts were written in the medieval period, in India and China as well as in the Western civilizations. These texts contained a combination of metallurgical, protochemical and iatrochemical knowledge along with its strange faiths and beliefs. The alchemists used the knowledge of metals, minerals and also that of the plant kingdom to design their elixir methods. In order to test the efficacy of the elixir, it was tried at first in the so-called transmutation processes. If proved successful it was looked upon as suitable for internal administration as well.

The purity of the ingredient was of utmost importance. The alchemist adopted various methods for purifying the metals and minerals. The metallurgical knowledge of the earlier metal-workers was applied in this particular direction in the medieval period. It was also enriched by the addition of new methods and reagents which the alchemist discovered in the course of his work.
A large number of chemical compounds were synthesized by the alchemist in his search for the elixir of life. They were oxides, sulphides, arsenides of various metals. Chemical as well as medicinal properties of these compounds slowly became known, thus developing iatrochemistry based on mercury compounds, in the late medieval period. Thus the study of alchemy helps us to understand the body of chemical knowledge on which the later development in the field of chemistry was based. A comparative study of alchemy in different culture areas will reveal the similarities and dissimilarities in these practices. A careful study of the medieval alchemical texts will help to ascertain the degrees of development in the given period. It will also reveal the extent of the transmission of ideas between them. When the philosophies behind these alchemical practices are understood, their characteristics could be correlated to the socio-economic or philosophical matrix in the given culture area.

Why Medieval Period?

The medieval period is of particular significance in studying the History of Science. It was immediately after this period that sciences progressed in the West, hand in hand with technology, resulting into the evolution of the modern society. Yet in ancient times both India and China had rich cultures of their own. Both were ahead of
Pre-Renaissance Europe in science and technology. However, sixteenth century onwards modern science emerged in Europe. Innumerable discoveries, industrial innovations, rise of modern civilization and a raised standard of living in the West changed the face of the world so much as to completely overshadow the old Asian cultures. These countries which were leading in mathematics, astronomy, physical sciences and technology a century or two ago fell behind the West. Their developments were rendered insignificant and obsolete.

Why did India and China fall behind? Why did they fail to maintain their pace and not develop themselves into modern countries? Why did natural science not sprout in India and China? What were the reasons and situations in which in European countries, at the time of the Renaissance and after, the seeds of scientific thinking and scientific spirit could germinate? Why could they manage the stupendous progress in a great many branches of natural science? These are the questions around which major discussions in the field of history of science now revolve. These are the issues which provide a theoretical perspective to the study of comparative developments. A number of sociologists, economists and historians have commented upon the causes of non-development of sciences
in the East, as well as those for its growth in the West. We give a brief account of it below.

Presuming the rise of science and modernization in the West to be the result of the capitalist civilization, Max Weber finds the origin of the Capitalistic spirit in Protestant Ethic. He has demonstrated in his thesis that there was more concentration of Protestants than Catholics in the capitalist enterprises and explained it in terms of motivational factors.

Since favourable conditions existed in Europe and elsewhere at other times also, which did not lead to the capitalist economy, the Protestant Ethic for him seems to be a logical cause of them at the time it actually arose. Thus religious movements could be said to have facilitated the new type of economic civilization.

E. N. Eisenstadt finds that the significance of Protestantism is not in any direct effect it had on economic, political or scientific activity but in the contribution it made towards restructuring of European society in general.

Weber argues that the essential characteristics of Protestantism are absent in the religions of either India or China. Considering the general cultural patterns he thinks that the absence of rational law based on the concepts of modern state, citizenship and also the absence
of the central, religiously determined and rational method of life led to the non-emergence of capitalist civilization and modern science in the East.

Using Weberian and particularly European scholarship John King Fairbank describes the factors inhibitory to the growth of science in China. He thinks the growth of science was stunted partly by the influence of Confucian scholarship which laid more stress on social harmony than any investigation of the Physical World. He also finds their system of logic at fault which stressed chain-reasoning rather than testing of ideas. He attributes the weakness in logic to the physical nature of Chinese written language. The ideographic script and its emphasis on memory were responsible for the separation of the intellectuals from the artisans, which is disastrous to the growth of science and technology. According to him the Orientals lacked in motivation rather than ability. Also the agrarian bureaucratic nature of a Confucian state was another aspect contributing to the non-development.

In Ming times the translations of Ptolemy's Almagest and Euclid's Elements were made in Chinese. Also Jesuit missionaries brought the latest scientific knowledge to China. The Chinese people, however, showed a great resistance to the assimilation of the spirit of Western Science. Mark Elvin ascribes this neglect to the growing
Xenophobia of the Chinese and intellectual isolation of the Chinese traditional empire. The later Ming emperors even discouraged trade with foreign countries which meant limitations to the expansion of the economic activity. A state of equilibrium was attained in economic and demographic expansions thus inhibiting further development.

In Needham's eyes the absence of the concept of laws of nature or a personal law-giver were responsible for the slow rate of scientific progress in China. In Wing tsit-Chan's eyes the pre-occupation of the Chinese with ethics and human affairs prevented the Neo-Confucian doctrine of "Investigation of things" from developing into natural science.

Needham, however, finds roots of scientific spirit in ancient Taoist philosophy which was in favour of study of nature rather than ethics and establishment of social harmony. In Weber's as well as Needham's eyes the lack of application of mathematical methods and the consequent inability to transform given data into abstract physical laws hindered progress of scientific theorization.

In Indian context, transcendentalism leading to lack of interest in mundane activities was probably the foremost reason of non-development of science. According to Hindu Philosophy the highest goal in life is "Moksha",
i.e., the final emancipation from material bondage. This is achieved when the sum total of good and bad deeds, while performing one's duties of this life, is positive. Again these duties are the ones assigned by the law-giver to the particular social group one belongs to. Brahmins was the only learned community and for them by principle, "austerity" was the highest virtue. Striving for the attainment of wealth or other comforts, which could have given an incentive for scientific research and technological progress, was considered a sin. Thus the only social group which was capable of intellectual exercise was totally disinterested in mundane activities, being wholly involved in religious, ritualistic matters with a transcendental goal.

In Hindu society, excessive stress on social harmony and also a social system in which profession was hereditary resulted into a separation of hands and brain which was disastrous for experimental science. The dependence on intuition rather than on experimentation and rational deduction was equally responsible. In P. C. Ray's view, the separation of intellectuals and artisans made the Indian soil intrinsically incapable of producing any Kepler or Newton, Harvey or Boyle.

From the point of view of availability of source material also the medieval period is the most suitable one.
It was a particularly productive period in the case of Indian and Chinese alchemy. We do find references to alchemy in earlier texts, but these references are of a vague and minor nature. Only in the medieval period, alchemy was practised with great enthusiasm and zeal. We find an abundance of alchemical texts with substantial evidence. These texts deal with philosophical, religious ideas behind alchemical practice as well as descriptions of practical methods. The number and scope of these texts show the popularity alchemy gained in this period among the people of all walks of life. Again after the fourteenth century alchemy slowly lost its vigour and glamour. This was probably due to the fact that, by this time, its futility was realised. Alchemical preparations were now discontinued and a new current of iatrochemistry emerged in the texts written after the fourteenth century, in which mercury and its compounds were used in medicinal formulations.

Chinese alchemy was at its prime in the seventh/eighth century AD. The Sino-Indian contacts were at their peak in the Tang dynasty (618-906 AD), through Buddhist travelers. Hence, from the point of view of tracing the transmission of scientific ideas between India and China, again the medieval period is the most suitable one.
Major Works

History of science is a much younger discipline than general history. History as a whole has existed as a branch of knowledge dealing with past events since time immemorial, but history of science emerged as a new field of study only in the twentieth century. Sciences played a minor role in people's lives in ancient times but it became the prime mover in socio-economic developments since the seventeenth/eighteenth century. Modern science and technology played an important role in the formation of modern civilization in the West and this fact aroused interest in historical circumstances leading to scientific discoveries leading to this branch of study.

In its evolutionary stage, history of science primarily dealt with the chronology of scientific events. As the field developed the new generation of "Science Historians" acquainted with both, science and humanities, thought in terms of the relation of scientific developments to the socio-economic developments, changes in patterns of ideas, attitudes and values. Currently, historians of science investigate the chain of historical facts which lead to a particular scientific discovery. The difference between history of science and other historical studies lies in the fact that the science historians also look into the actual subject matter of the sciences.
Certain fields like astronomy, medicine and mathematics were the first to attract the attention of the historians of science. Alchemy and chemistry are among the less trodden fields. Scholars like Stillman, Partington, Read, Thorndyke, Leister, Hopkins, and Boas wrote volumes on the history of Western alchemy and chemistry. Studies in the history of chemistry of Eastern civilizations are but scant.

Major work done in the field of Chinese alchemy is the series of volumes on "Science and Civilization in China" by Joseph Needham and his collaborators. The fifth volume of the above series deals with metallurgical and physiological alchemy, protochemistry and chemical technology from the third century B.C. to the seventeenth century AD; i.e., to the introduction of modern chemical ideas into China by European travelers and missionaries. Needham gives an account of a large number of texts and demonstrates how alchemy progressed in China, its philosophical basis, practical recipes and the mass of chemical knowledge that the Chinese gathered in the process.

In the above works, at a large number of places, we find references to India and to the visits by Indian Buddhist monks and travelers who introduced certain alchemical and chemical ideas into China. These cases, if investigated in depth, would give interesting information
about such transmissions. Needham mentions Indian alchemy only in light of the remarks made by Chinese travelers in their accounts and those found in some of the Chinese texts and dynastic records.

Works such as "Chinese Alchemy - Preliminary Studies" by Nathan Sivin; "Alchemy in Ming China", "An Introduction to Science and Civilization in China" by Ho Peng-Yoke; "Alchemy, Medicine and Religion in the China of AD-320" by James Ware are very illuminating. Further, there are books published in Japan such as "Medieval Chemistry (alchemy) and the Arts of Immortality" by Yoshida Mitsukuni and "Studies in the History of Medieval Chinese Science and Technology" by Yabuuchi Kiyoshi. On the whole, one may say that Chinese alchemy and proto-chemistry have been given some attention by scholars, European as well as Chinese and Japanese. In the case of Indian alchemy the picture is quite different.

The only profound study of the subject has been made by Prafulla Chandra Ray in his volumes on Hindu Chemistry, which are later condensed in a single volume, "The History of Chemistry in Ancient and Medieval India" by Priyadānandana Ray. An account of a large number of Sanskrit texts is given in this volume, with some discussion and translations of selected verses. It depicts the main chemical and alchemical practices and the overall trend
over the period ranging from the prehistoric to the sixteenth century AD. P. C. Ray considers Indian alchemy as an independent development which slowly took place over a long period. However, he does not suggest the possibility of any foreign influence on Indian alchemy or vice versa; whereas Needham is quite positive about the fact that a good amount of exchange must have taken place between these neighbouring culture areas and that deeper and thorough research is needed to establish these chemical contacts.

A Sanskrit alchemical text, "Rasārnavakalpa", has been edited and translated into English by Meera Roy and B. V. Subbarayappa. In the Concise History of Sciences of India, Subbarayappa gives an account of many of the available Rasāyana texts in Sanskrit, Tamil, etc., their general content, and the basic philosophies supporting the practices discussed therein. Early chemistry, metallurgy from the pre-vedic period (1500 B.C.) to the late medieval period (15th century AD) is narrated in this chapter. Mahadihasan has also studied the subject of alchemy in this region in some detail, particularly the philosophical aspect of it.

No effort has so far been made to study Chinese and Indian alchemy in a comparative fashion, or to look into the exchange of scientific ideas and techniques between them.
It is universally known that the Chinese invented gun-powder, paper-making and printing techniques in the medieval period. The situation is not so clear and unambiguous in other cases such as the origin of alchemical ideas, the use of mercury in the transmutation of metals and in the elixir-syntheses, about the discovery of mineral acids and also about the usage of certain metals like zinc. Further research based on comparative study of Indian and Chinese texts of the medieval period will establish the origin and transmission of many of the above scientific ideas with some certainty.

Buddhist texts which were translated from Sanskrit to Chinese between the second century AD to the thirteenth present themselves as important sources for studying transmission of ideas. Though chiefly these deal with Buddhism, some of these texts deal with secular subjects as well. We find references to alchemy and Buddhists' interests in it, in a number of translated texts, indicating the possibility of exchange of alchemical ideas.

In this thesis we will discuss how far chemical and alchemical processes of Indian and Chinese alchemy were related and discuss the similarities and dissimilarities between them. One of the main objectives would be to throw more light on transmission of scientific ideas, especially
alchemical and protochemical ideas, between India and China in the medieval period. Thus this work will attempt to fill the lacuna in the studies of Indian alchemy and in the fields of comparative alchemies.