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The Compositional Study of Qajar Silver Coins Using PIXE Technique; Case Study of Coins of Naser al-Din Shah Qajar of Tabriz Mint

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Abstract: The study of the elemental composition of silver coins minted in the Tabriz during the Qajar period can help to investigate the socio-economic situation of that period. In this case study, Proton-Induced X-ray Emission (PIXE) analytical technique has been applied to twenty-eight Qajar silver coins selected from a private collection. the purpose was to study and investigate the changes in silver elements in Qirans of Nasser al-Din Shah Qajar in Tabriz mint. The metallic elements Ag, Cu, Fe, Pb, and Au were observed. The results show that the content of Ag the main constituent of the coins varies from 90.07 to 82.88%. this significant variation in the content of the major constituent reveals the economic difficulties encountered by the dynasty. The results, which are shown by using the PIXE technique, brought to light valuable information about the economy of the period under study.

Keywords: *Silver Coin, Qajar, Naser al-Din Shah, PIXE Analysis*.

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Introduction

The study of ancient coins may serve as an indication of the economic and political circumstances at the time of their production. Qājār dynasty, the ruling dynasty of Iran from 1794 to 1925 A.D. In 1779 A.D., following the death of Moḥammad Karīm Khān Zand, the Zand dynasty ruler of southern Iran, Āghā Moḥammad Khān (reigned 1779–97 A.D.), a leader of the Turkmen Qājār tribe, set out to reunify Iran. By 1794 he had eliminated all his rivals, including Loṭfʿ Alī Khān, the last of the Zand dynasty, and had reasserted Iranian sovereignty over the former Iranian territories in Georgia and the Caucasus. In 1796 A.D. he was formally crowned king. Agha Moḥammadkhan was assassinated in 1797 A.D. and was succeeded by his nephew, FatḥʿAlīShāh (reigned 1797–1834 A.D.). Fathʿ Alīshah attempted to maintain Iran's sovereignty over its new territories, but he was disastrously defeated by Russia in two wars (1804–13 A.D., 1826–28 A.D.) and thus lost Georgia, Armenia, and northern Azerbaijan. Fatḥʿ Alī's reign saw increased diplomatic contacts with the West and the beginning of intense European diplomatic rivalries over Iran. He died in 1834 A.D. and Mohammad Mirza son of Abbas Mirza succeeded him, who fell under the influence of Russia and made two unsuccessful attempts to capture Herāt. When Moḥammad Shāh died in 1846 A.D. the succession passed to his son Nāṣer od-Dīn (reigned 1846–96 A.D.) (Zargarinezadeh 2016). Tehran's modern transformation took place by the order of ruling monarch Naser al-Din Shah Qajar (1846-96 A.D.). The rule of Naser al-Din Shah is divided into three periods: 1- the period of turmoil (1263-1275 A.H. / 1846-1859 A.D.); 2- the period of peace and prosperity (1275-1309 A.H. / 1859-1891 A.D.); 3- the period of weakness (1309-1314 A.H. / 1891-1896 A.D.). Serious disturbances broke out when succeeded his father to the throne in 1846 A.D., the most important problems of the first period are Khorasan Riots and the Babi uprising, but these were quelled through the efforts of his chief minister, MīrzāTaqī Khān. Under TaqīKhān's influence, Nāṣer al-Dīn began his rule by instituting a series of needed reforms. The government's policy for guaranteeing the money value based on metal millesimal fineness was writing some laws and employing some people for supervising their administration; moreover, the monetary system of the Qajar era was established on Safavid era laws. The Qiran was the official currency of Iran. Its use as currency dates back to the time of Fath-Ali Shah of the Qajar dynasty. This system was so much chaos in the Naseri era that the coins were somehow considered local. In every city, silver Qirans have minted at different millesimal finenesses and their exchange rate was quite different from gold TomanThethe currency of a city, with the same nominal value, was not accepted in other cities without subtracting the exchange rate (Matte et al. 2017: 281-282).

During this period (1849-1859 A.D.) there were thirty silver mints and until Mirza Hussein Khan Sepahsalar there was no central mint and every important city of the country had a mint. Since the coins were considered to be local species and each city minted a different alloy of silver Qiran, coins were minted in Tabriz, Qazvin, Rasht, Isfahan, Kerman, Mashhad, Shiraz, etc. in addition to Tehran. The value of Iranian currency varied each city had silver coins of equal value that were not accepted in other cities. The coins were hand-minted in the Qajar era, therefore, every city and state, based on economic needs, had its mint in which the amount of minting coins depended on the financial power. Nasserite-era mints can be divided into three groups based on research: Active mints: Mashhad, Tabriz, Tehran, Isfahan, and Shiraz; 2. Common Mints: Hamedan, Qazvin, Astarabad, Tabarestan, Kerman, Kashan, Rasht, Herat, Yazd, Kermanshah, and Khoy; And 3. Ceremonial mints: Sarakhs, Sistan (Album 2011: 291-296; Michael, 2015: 79-80), Shushtar and Rokab (Novineh Farhbakhsh, 2005: 109). Mints minted gold, silver, and copper coins in different currencies and weights depending on location. Rabbi studied examples from the local mint and believes that these figures indicate weight differences in Iranian currency (Rabino, 1892: 37). Abbot pointed out that many cities have their monetary criteria, but he noted that a common criterion for business is the official currency of the country. For example, Yazd had its own money in 1894-1850 A.D. (1265-1266 AH..), which was different from other places, according to Abbott's writings. 25 Shahis were considered Saheb-Qiran and the usual 12.5 Qiran was equal to 1 Toman, while every 10 Qiran was supposed to be 1 Toman. This coin is acceptable for small businesses but 20 Shahi Qira is acceptable for big businesses. According to him, the local Qirans in Kerman were 28 Shahi and 3.5 Panabadi, and Kerman 2 Shahi was the criterion for a Qiran coin. In addition, the Isfahan currency was 23 shahs for each Qiraan, but for large trade, the Iranian currency is acceptable (Abbot, 1983: 82, 85, 102, 117). One reason for such changes, at least before the establishment of the modern mint in 1294 A.H., was that local mints had little adherence to the formal weight. However, even after the establishment of the modern mint minting of coins of the same weight and millesimal fineness, the local monetary system continued working. Landor who was traveling in Iran in 1901 A.D. (1319 A.H.) stated that “I never exactly knew the value of 1 Qiran; in every state, I received different Shahis for the same Qirans (Landor, 1902: 131). Tabriz was not an exception, and numerous local silver Qirans with no clear value were now and then minted from 1265 to 1294 A.H. The purpose of this article is to investigate the changes in silver elements in Qirans of Nasser al-Din Shah Qajar in Tabriz mint, to identify political events in the period of Nasser al-Din Shah's rule have been influential in reducing the weight of silver that done by PIXE analytical technique.

Materials and Methods

Selection of Coins

Due to the long rule of Naser al-Din Shah, his silver coins were selected for PIXE analysis. these coins belong to a private collection of Seyed Hassan Sadat Razavi. The studied coins belong to Tabriz Mint, which in the period of 1265-1283-1288, 1290-1291and 1293-1294 A.H., multiplied (Album, 2011: 291-296; Michael, 2015: 796). The design of Naser al-Din Shah's Qurans minted in Tabriz is like other coins of this era in other cities; Obverse on these coins, the words "Sultan Ibn Al-Sultan Nasser al-Din Shah Qajar" are written, and reverse of the coins, the words "Multiplication of Tabriz Sultanate [date of multiplication of coins by number]" can be seen (Figure 1).

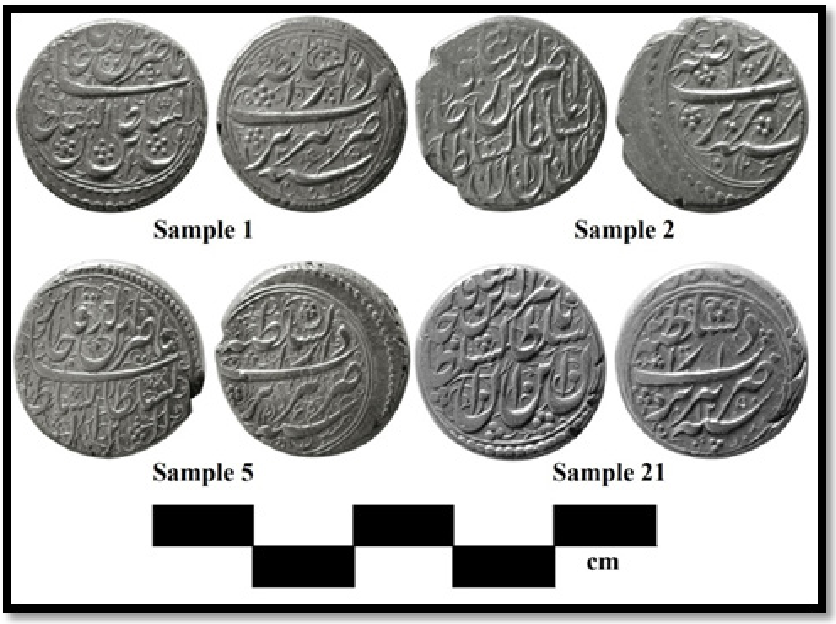


Fig. 1: Silver coins of Naser al-Din Shah of Tabriz Mint

Twenty- eight silver coins have been cleaned as follows: they have been kept in 3-5% formic acid solution for a few minutes, scrubbed with a toothbrush, and finally cleaned with alcohol-soaked cotton and sent to the laboratory (Table 1).

Table 1: Characteristics of the coins Naser al-Din Shah of Tabriz Mint

Sample No	Date	Weight	Sample No	Date	Weight
1	1265 AH/ 1849 AD	5.32g	2	1266 AH/ 1850 AD	5.17g
3	1267 AH/ 1851 AD	5.27g	4	1268 AH/ 1852 AD	5.25g
5	1269 AH/ 1853 AD	5.38g	6	1270 AH/ 1854 AD	5.31g
7	1271 AH/ 1855 AD	5.24g	8	1272 AH/ 1856 AD	5.33g
9	1273 AH/ 1857 AD	4.92g	10	1274 AH/ 1858 AD	4.96g
11	1275 AH/ 1859 AD	4.95g	12	1276 AH/ 1860 AD	4.88g
13	1277 AH/ 1861 AD	4.99g	14	1278 AH/ 1862 AD	4.93g
15	1279 AH/ 1863 AD	4.95g	16	1280 AH/ 1864 AD	4.92g
17	1281 AH/ 1865 AD	4.82g	18	1282 AH/ 1866 AD	4.87g
19	1283 AH/ 1867 AD	4.94g	20	1288 AH/ 1871 AD	4.88g
21	1290 AH/ 1873 AD	4.97g	22	1291 AH/ 1874 AD	4.93g
23	1293 AH/ 1876 AD	4.91g	24	1294 AH/ 1877 AD	4.96g
***	***	***	***	***	***
25	1274 AH/ 1858 AD	4.89g	26	1275 AH/ 1859 AD	4.94g
27	1283 AH/ 1867 AD	4.93g	28	1288 AH/ 1871 AD	4.86g

Method

Utilizing the PIXE technique to study ancient coins is one of the prevailing methods for finding the chemical composition of ancient metals (Smith, 2005: 258-264). In this case study, Proton- Induced X-ray Emission (PIXE) analytical technique has been applied to twenty-eight Qajar silver coins selected from a private collection. Analyses were carried out in the Van de Graff accelerator of the Atomic Energy Organization of Iran (AEOL). A 2 MeV proton beam with a current of 2-3 nA was used to bombard the coins. Then coins were inserted in a multipurpose scattering chamber maintained in a high vacuum (10-5Torr). The emitted characteristic X- rays were detected with an ORTEC Si (Li) detector (FWHM 170 eV at 5.9 keV). GUPIX takes into account; the energy loss of the 2 MeV incident protons, the variation of X-ray production cross-sections with the decreasing proton energy, the absorption of X- rays from different depths in the target, and the elemental effect, also used all the inputted specifications of the Si (Li) X-ray detector to generate a theoretical curve for its efficiency and allows for the escape peak, sum peak and low energy tailing of X-ray (Ben Abdelouahed, 2010; Campbell et al. 2000; Sodaei 2013, 2016).

Result and Discussion

The results are shown in Table 2. In the coins under study, the metallic elements Al, Si, S, Cl, Ca, Ti, Mn, Fe, Ni, Cu, Zn, Br, Ag, Au, Hg, and Pb were observed (Table 2). The most abundant elements after silver (Ag) are copper (Cu), iron (Fe), lead (Pb), and gold (Au).

The silver purity grade of these coins is between 82.03 and 90.11 %; the difference between the maximum and minimum silver purity values is 8.08 % (Table 3). Based on Tables 1 and 2 the silver purity percentage column, it is possible to observe the silver purity changes during the

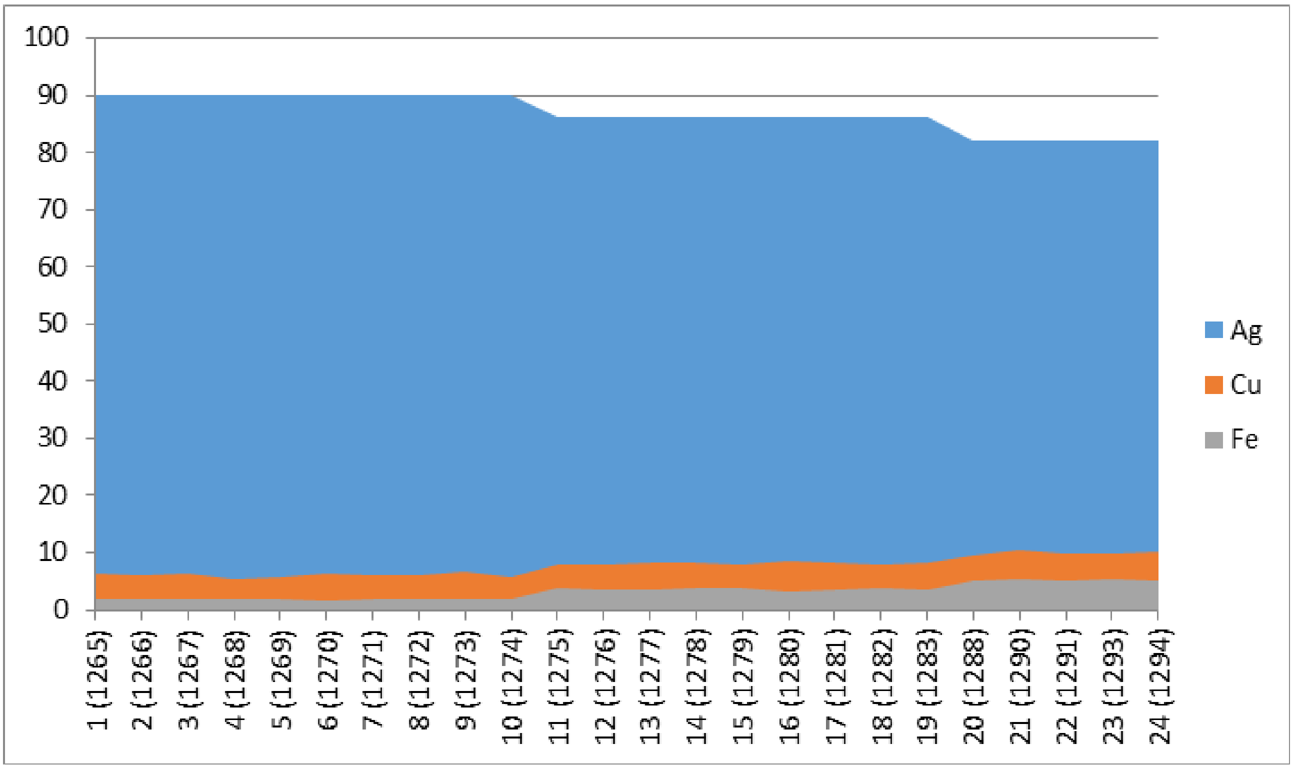
Table 2: The relative amounts of the constituent elements of coins tested in terms of weight percentage																
No	Al	Si	S	Cl	Ca	Ti	Mn	Fe	Ni	Cu	Zn	Br	Ag	Au	Hg	Pb
1			0.07					1.88		6.32			90.03	0.77		0.93
2						0.08		1.93		6.17			90.05	0.89		0.88
3						0.08		1.79		6.19		0.29	90.11	0.76		0.78
4		0.19		0.14	0.17		0.19	1.95		5.25			90.09	1.03	0.16	0.83
5	0.09							1.82	0.22	5.76	0.17		90.06	0.99		0.89
6			0.12					1.55		6.33			90.05	1.14		0.81
7			0.09					1.94		6.08			90.02	0.97		0.90
8						0.11		1.85		6.17			90.07	0.81		0.99
9						0.07		1.97		6.63			90.01	0.55		0.77
10				0.16	0.19	0.13	0.23	1.90		5.75			90.10	0.69		0.85
11	0.08	0.18					0.18	3.76	0.13	7.78			86.22	0.85		0.82
12	0.11	0.20						3.65		7.91			86.34	1.05		0.74
13	0.08						0.17	3.52		8.14			86.29	0.92		0.88
14	0.09							3.81	0.11	8.20			86.15	0.73		0.91
15		0.17						3.79		8.08			86.31	0.88		0.77
16		0.24						3.18		8.72	0.21		86.19	0.63		0.83
17	0.10		0.09					3.45		8.36			86.25	0.76		0.99
18						0.12		3.71		8.04	0.22		86.22	0.94		0.75
19						0.14		3.61		8.22			86.18	1.01		0.84
20	0.11	0.15	0.13	0.17	0.20	0.12	0.16	5.01	0.11	9.36	0.12	0.33	82.11	0.82	0.19	0.91
21				0.22	0.28			5.37		10.31			82.03	0.96		0.83
22			0.14	0.17	0.19	0.09		5.16		9.99	0.19		82.09	0.91	0.18	0.89
23		0.13	0.17	0.23	0.26			5.27		9.84		0.32	82.16	0.79		0.83
24				0.22	0.25			5.11		10.12		0.31	82.14	0.90		0.95

whole minting period. The silver purity average has been 90.05% between 1265 and 1274 A.H., but it has been 86.23% between 1275 and 1283 A.H. and 82.10% between 1288 and 1294 A.H. (Figure 2). Fig. 2 shows the quality and decline in the value of Qirans minted in Tabriz.

Therefore, it can be said that between the years 1274-1275/ 1858-1859 and 1283-1288 AH/ 1867-1871, the purity of silver decreases from 90% to 86% and from 86% to 82%. and retesting on new coins is essential for accurate results and analysis. For this reason, 4 coins with multiplication dates of 1274, 1275, 1283/ 1858, 1859, 1867, and 1288 AH/ 1871 were sent to the laboratory. The test results of these coins (Table 4) overlap with the test results of the original coins (Table 2) and this can confirm the accuracy of the analysis (figure 3).

Copper metal is usually present naturally in coins of less than 2%, but if the amount of this element is more than 2%, it cannot be considered natural and must have been optionally blended (Hughes & Hall, 1979: 321-344). The coins of this study have an amount of 5.25-10.31% copper, with a difference of 5.06% between the lowest and highest purity of copper (Figure 2); According to Table 4 and the column of the percentage of copper purity, it is possible to change the purity of copper between the years 1265-1274 AH. With an average of 6.06%, 1275-1283 AH. With an average of 8.16% and 1288-1294 AH. With an average of 9.92%, it was seen (Fig-

Table 3: The minimum and maximum limit of the main metal elements of the coins tested					
***	Ag	Cu	Fe	Pb	Au
The minimum	82.03	5.25	1.55	0.74	0.55
The maximum	90.11	10.31	5.37	0.99	1.14



Fig, 2: Chart of the reduction changes of a silver element compared to the rate of increase changes of copper and iron elements

ure 3) that this could indicate that the metal was intentionally added to lower the purity of the silver. Also, the presence of iron is usually due to surface contamination (Flament & Marchetti, 2004: 179-184; Tripathy et al. 2010), The amount of iron in coins is between 1.55-5.37%, with a difference of 3.82% between the lowest and highest purity of iron (Fig. 3); According to Table 4 and the percentage of iron purity column, it is possible to change the purity of iron between the years 1265-1274 A.H. With an average of 1.85%, 1275-1283 A.H. With an average of 3.60% and 1288-1294 A.H. With an average of 5.18%, consider (Fig. 3) this is an indication of its addition to adjusting the purity of the silver metal of the coins. Because silver is extracted from lead mines (Hughes & Hall, 1979: 321-344), the presence of low amounts of lead (1% and less) is observed in silver coins. If the amount of lead is higher, it indicates insufficient accuracy in the extraction of silver metal (Flament & Marchetti, 2004: 179-184). The amount of lead in the analysis of silver coins is 0.85%, which in addition to the type of mine indicates low accuracy in silver mining.

Conclusion

A PIXE study was conducted on Qajar Iranian coins. Based on the results obtained, the most important and important components are copper, silver, gold, zinc, and lead. The study also shows the evolution of fineness in silver production from the early reign of Naser al-Din Shah to machine-making. Concentrations of Ag, presumably the main component of the coins, range

Table 4: The relative value of the constituent elements of the coins of the turning points

No	Al	Si	S	Cl	Ca	Ti	Mn	Fe	Ni	Cu	Zn	Br	Ag	Au	Hg	Pb
25				0.19	0.22	0.11	0.17	1.98		5.76			90.07	0.63		0.87
26	0.07	0.15	0.17				0.15	3.55	0.11	7.68		0.21	86.31	0.81		0.79
27								3.51		8.42			86.21	0.95		0.91
28	0.09			0.18	0.21			4.98		10.07	0.11	0.28	82.18	0.77	0.17	0.96

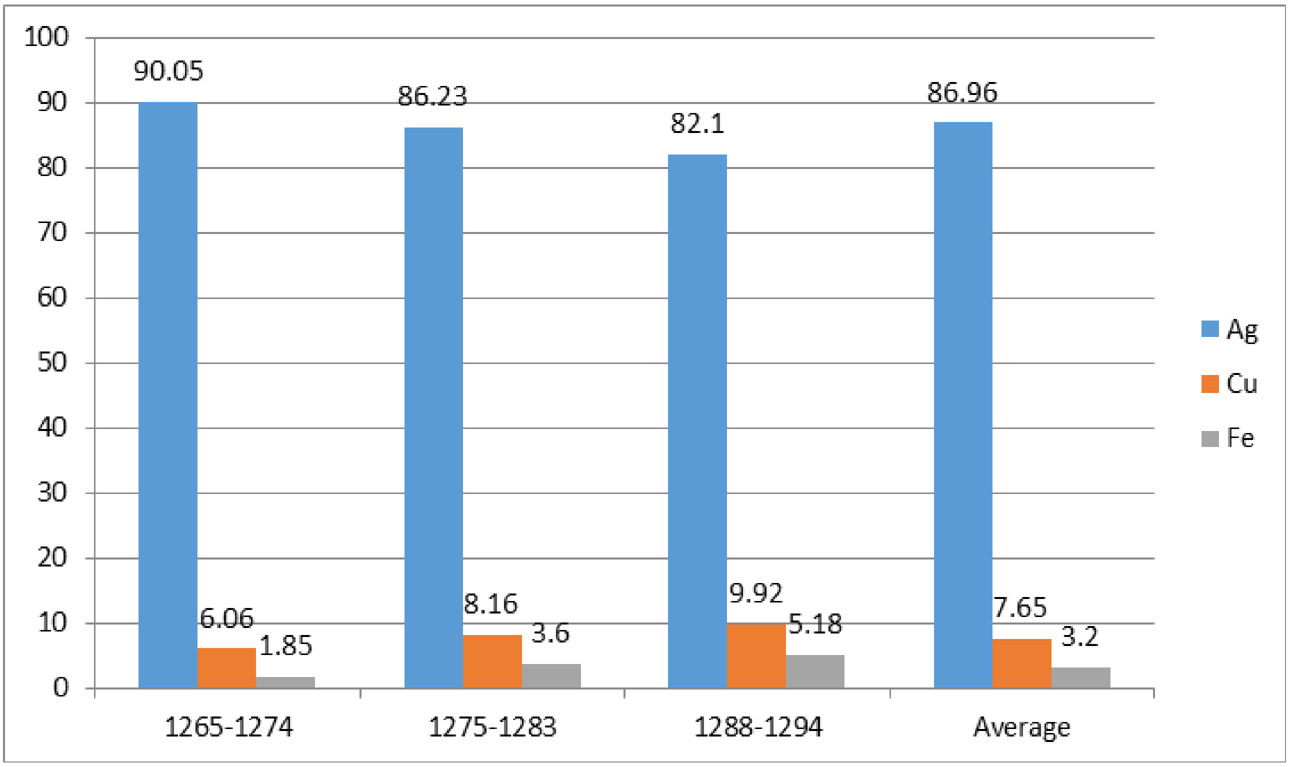


Fig. 3: Chart of changes of the main elements (silver, copper, and iron) in the coins tested

from 82.14 to 90 %. This significant difference in the concentration of the most important component indicates the economic difficulties of the dynasty. Fluctuations in the amount of Cu in the silver coins of King Naser al-Din Shah indicate that their reign faced a political problem and that Cu was deliberately added to silver not only for tempering purposes but also for economic reasons. The presence of Cu in the samples is evidence of the political concerns of that time. Thus, it can be argued that metal producers deliberately added Cu to these silver alloys to reduce costs. Thus, the political events of the first period of Nasser al-Din Shah (1848-1859 A.D.) contributed to the decrease in the weight of silver. The low amounts of Pb and Zn in both periods indicate their relative purity. It can also be concluded that their mineralogy and metallurgy were relatively developed during that period.

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