

**EXPERIMENTAL STUDY OF GOLD SOLUBILITY IN LOW-DENSE GAS-VAPOR PHASE OF THE SYSTEM  $\text{Au}+\text{H}_2\text{O}+\text{H}_2\text{S}+\text{Cl}$  UNDER HYDROTHERMAL CONDITIONS**  
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At present a transport of gold in dense aqueous solutions at elevated temperatures and pressures is studied rather well. For low-dense gas vapor solutions data on gold solubility have only appeared lately and so far are restricted in composition. On the basis of some experimental investigations and numerous geological observations a geochemical bond of gold and sulfur, hydrogen sulfide and chlorine is well known. In the system  $\text{Au}+\text{HCl}+\text{H}_2\text{O}$  [1] data on considerable solubility of gold in aqueous hydrochloric acid fluid and presence of  $\text{AuCl}_m(\text{H}_2)_n$  complex in gaseous phase are obtained. On the other side, it is known that such components as water, sulfur, chlorine and hydrogen sulfide predominate in the composition of high-temperature hydrothermal fluids; a composition of volcanic gases testifies to this very fact. A study of fluid inclusions in minerals formed at temperatures 400-700°C also shows that gold tends to concentration in gaseous phase [2]. With this respect a problem of experimental and theoretical investigation of gold behavior in low-dense gas-vapor solutions of the system  $\text{Au}+\text{H}_2\text{O}+\text{H}_2\text{S}+\text{Cl}$  has been formulated, what will make it possible to get quantitative data on gold transfer in gaseous phase, gold distribution between liquid and gaseous phases and conditions of its mobilization. A device created by us and representing a reactor made of titanium alloy, passivated in nitric acid, has been used. The capsule also made of the alloy Bt-8 is placed inside the autoclave. It can be hermetically locked at any parameters in the process of the runs using specially designed valve, which allows sampling of the gas phase “in situ” [3]. The reactor is heated in a nongradient zone of resistance furnace, having two independent windings where current is regulated by high accurate temperature regulators BPT-3 and is controlled by two Cr-Al thermocouples. Pressure is measured during the whole run by pressure transducer D-100. For this purpose a titanium capillary supplied with a microvalve is welded into the reactor obturator. As  $\text{H}_2\text{S}$  source, tioacetamide ( $\text{CH}_3\text{CSNH}_2$ ) has been used which in the presence of the acid quickly decomposes with separation of stoichiometric quantity of hydrogen sulfide. In this case  $\text{H}_2\text{S}$  is predominant a compound, which contains sulfur [4].

The results of the experiments on gold solubility are given in the table.

NN exper.	t°C	P, atm.	m <sub>HCl</sub>	m <sub>H<sub>2</sub>S</sub>	liquid phase m <sub>Au</sub> •10 <sup>6</sup>	condensate m <sub>Au</sub> •10 <sup>6</sup>
9	350	184	0.1	0.1	0.573	2.44
10	350	210	0.1	0.1	1.71	11.6
1	400	500	0.01	0.1	2.17	10.5
3	400	390	0.1	0.1	3.90	no sample
5	400	295	0.1	0.1	6.15	no sample
6	400	297	0.1	0.1	4.87	no sample
7	400	290	0.1	0.1	4.57	no sample
11	440	350	0.1	0.1	5.47	36.5
13	440	335	0.1	0.5	65.85	141.0

While studying systems with participation of elements of variable valency, the control of oxygen fugacity is very important. We used magnetite-hematite couple, as an oxygen buffer. After each run buffer composition was determined by the x-ray phase analysis. To hold the run, a gold plate was fixed in the upper part of the reactor, but the buffer mixture in the titanium container and tioacetamide charge were placed at the bottom of the reactor. The solutions of hydrochloric acid were used as a solvent. A "hot" valve locked an empty internal capsule, the reactor was also hermetically closed and put into the furnace for heating. While reaching the necessary temperature (350, 400, 440°C) the internal capsule was opened and the whole system was kept in such a condition during 7-10 days at a constant control of temperature and pressure. After that the internal capsule was locked and the autoclave was quenched in running cold water. As a result of the run, a condensate of gas-vapor phase was concentrated in the internal capsule, but at the bottom of the reactor there was a solution of liquid phase with gold dissolved in them. After a quantitative collecting of gold dissolved in both phases as well as on the walls of the capsule and the reactor during the quenching process, its content was determined in a chemical laboratory of the IMET RAS by atomic-emission spectroscopy method with induction plasma using plasma spectrometer UITIMA-2, "Jobin Ivon" company, France.

It can be seen from the table that as temperature and concentration of hydrogen sulfide in the system rise, gold solubility increases markedly. Moreover the gold solubility significant more in gas-vapor phase, than in liquid phase. That is the transport gold in hydrothermal sulfide-bearing systems preferable in gas-vapor phase. We continue to study this system.

## References

1. Archibald S.M., Migdisov A.A., Willamds-Jones A.E. The stability of Au-chloride complexes in water vapor at elevated temperatures and pressures // *Geochim. Cosmochim. Acta*. 2001. V.65. N. 23. PP. 4413-4423.
2. Ulrich T., Gunther D., Heinrich C.A. Gold concentrations of magmatic brines and the metal budget of porphyry copper deposits // *Nature*. 1999. V. 399. PP. 676-678.
3. Zakirov I.V., Sretenskaya N.G. The procedure used in the experimental determination of phase compositions under heterogeneous conditions // *Experimental problems of geology*. M.: Nauka. 1994. PP. 664-667.
4. Dadze T.P., Kashirtseva G.A., Ryzhenko B.N. To quantity and forms of existence of gold in sulfide-bearing solutions at T=300°C // *Geokhimiya*. 2000. N. 7. PP. 780-784.

*The work is done under RFFI support 05-05-64206*

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*Electronic Scientific Information Journal "Herald of the Department of Earth Sciences RAS" № 1(24) 2006*  
ISSN 1819 – 6586

*Informational Bulletin of the Annual Seminar of Experimental Mineralogy, Petrology and Geochemistry – 2006*  
URL: [http://www.scgis.ru/russian/cp1251/h\\_dggms/1-2006/informbul-1\\_2006/hydroterm-5e.pdf](http://www.scgis.ru/russian/cp1251/h_dggms/1-2006/informbul-1_2006/hydroterm-5e.pdf)

*Published on July, 1, 2006*

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