Thermodynamic analysis of Mn-As-H_2O, Mn-Sb-H_2O, Mn-Bi-H_2O systems

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***Abstract*—**A thermodynamic analysis of Mn-As-H_2O, Mn-Sb-H_2O, Mn-Bi-H_2O systems was made through calculation and drawing diagrams of E-pH, where the boundaries of the area of sustainability and formation of arsenates, antimonates and bismuthates of manganese are clearly shown.

***Keywords*—** Antimony, arsenic, bismuth, diagram of the E-pH.

I. INTRODUCTION

IN the production of nonferrous metals, arsenic, antimony and bismuth are harmful impurities. During copper electrolysis, their transition from anode copper to solution and contamination of the electrolyte are happening. The accumulation of significant quantities of harmful impurities in the electrolyte may cause a resistance increase, the solution viscosity, resulting in over-expenditure of electricity, which poses the problem of the withdrawal from circulation and purification of electrolyte copper-melting production.

In world practice, different techniques are used for these purposes, their analysis shows that there is still a question of purifying electrolyte, because applied methods do not allow to reach a deep degree of solutions cleaning. Arsenic, antimony-, and bismuth compounds circulate in many metallurgical processes of nonferrous metallurgy, complicating the course of technological processes, thereby reducing their cost-effectiveness.

Development of complex processing of copper electrolyte with arsenic, antimony and bismuth exclusion in environmentally friendly forms require a preliminary thermodynamic analysis to predict the behavior of the copper electrolyte components during cleaning process.

For the purpose of theoretical justification of physical and chemical laws in process of hydrolytic deposition of arsenic, antimony and bismuth from copper electrolyte by manganese-containing compound thermodynamic analysis of Mn-As-H_2O, Mn-Sb-H_2O, Mn-Bi-H_2O systems was made.

II. MATERIALS AND METHODS

By calculating and charting E-pH diagrams, the boundaries of the area of sustainability and boundaries of formation of arsenates, antimonates and manganese bismuthates are clearly shown. Data analysis of diagrams allowed to solve a number of issues related to the chemical reactions in the studied systems, the direction of the reactions and resistance components of the phases, to evaluate the thermodynamic behavior of the chemical elements and their compounds, to set limits on capacity and pH, in which the compound is sustainable, to identify the chemical nature of oxidation, recovery products.

Fig. 1 is a diagram of the E-pH Mn-As-H_2O system at standard conditions (25°C and a total pressure of 1 atm.), firstly built with all forms of ortho- and metaarsenic acid-pH diagrams of E-pH As-H_2O and Mn-H_2O systems. Line 1, 2 on E-pH diagram correspond to the upper (oxidizing environment) and lower (reducing environment) boundaries of water sustainability.

All equations of As-H_2O systems reactions are indicated by dash-dotted lines. The main formula in the oxidative area of arsenic in the range pH 0-2,19 is undissociated H_3AsO_4, in the pH range equal to 2,19 -6,79 - H_2AsO_4, at pH values from 6.79 to 11.51 dominates $HAsO_4^{2-}$- ion. At pH> 11.51, AsO_4^{3-}- anion appears. In recovering environment, undissociated H_3AsO_3- arsenic acid, is stable, which with an increase in pH will be replaced by $H_2AsO_3^-$, $HAsO_3^{2-}$, and AsO_3^{3-}. H_3AsO_3 oxidation by increasing the values of the potential lead to the formation of H_3AsO_4, $H_2AsO_4^-$ or $HAsO_4^{2-}$ ions; and H_2AsO_3- can be oxidized to $HAsO_4^{2-}$ and AsO_4^{3-} (reaction equation from 3 to 28 of Table I).

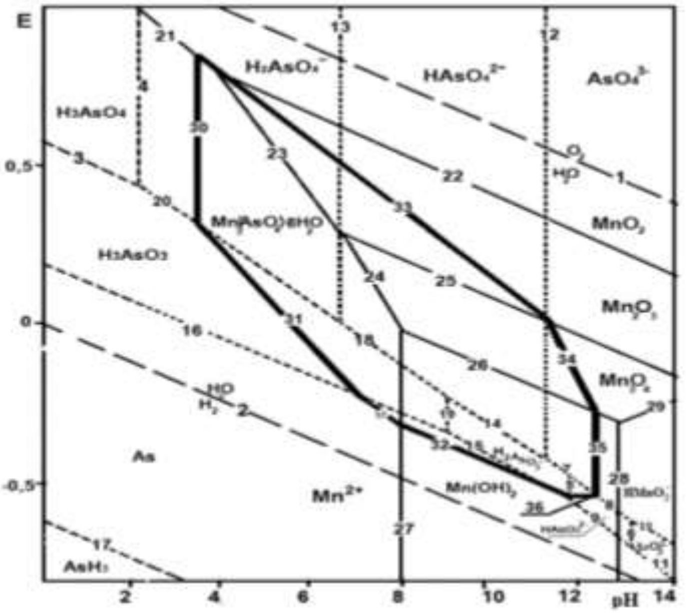

Fig. 1 E-pH system diagram Mn-As-H_2O

This work was sponsored by E.A. Buketov Karaganda State University, Ministry of education and science (№0437) of the Republic of Kazakhstan.

http://dx.doi.org/10.15242/IICBE.C0816212

TABLE I

System interaction equations Mn-As-H_2O

№	Chemical reactions	Electrode reactions
1	$H_2O_{(l)}=O_{2(g)}+4H^+_{(l)}+4\bar{e}$	E=1,23-0,059pH
2	$H_{2(g)}=2H^+_{(l)}+2\bar{e}$	E=-0,059pH
3	$H_3AsO_{3(l)}+H_2O_{(l)}=H_3AsO_4+2H^+_{(l)}+2\bar{e}$	E=0,586-0,059pH
4	$H_3AsO_{4(l)}=H_2AsO^-_{4(l)}+H^+_{(l)}$	lgK_p=-pH; pH=2,2
5	$H_2AsO^-_{3(l)}=HAsO_3^{2-}{}_{(l)}+H^+_{(l)}$	lgK_p=-pH; pH=12,1
6	$HAsO_3^{2-}{}_{(l)}=H^+_{(l)}+AsO_3^{3-}{}_{(l)}$	lgK_p=-pH; pH=13,4
7	$H_2AsO^-_{3(l)}+H_2O_{(l)}=AsO_4^{3-}{}_{(l)}+4H^+_{(l)}+2\bar{e}$	E=0,925-0,118pH
8	$HAsO_3^{2-}{}_{(l)}+H_2O_{(l)}=AsO_4^{3-}{}_{(l)}+3H^+_{(l)}+2\bar{e}$	E=0,567-0,088pH
9	$As_{(s)}+3H_2O_{(l)}=HAsO_3^{2-}{}_{(l)}+5H^+_{(l)}+3\bar{e}$	E=0,65+0,02lg[$HAsO_3^{2-}$]-0,1pH
10	$AsO_3^{3-}{}_{(l)}+H_2O_{(l)}=AsO_4^{3-}{}_{(l)}+2H^+_{(l)}+2\bar{e}$	E=0,170-0,059pH
11	$As_{(s)}+3H_2O_{(l)}=AsO_3^{3-}{}_{(l)}+6H^+_{(l)}+3\bar{e}$	E=0,892-0,118pH
12	$HAsO_4^{2-}{}_{(l)}=H^+_{(l)}+AsO_4^{3-}{}_{(l)}$	lgK_p=-pH; pH=11,5
13	$H_2AsO^-_{4(l)}=HAsO_4^{2-}{}_{(l)}+H^+_{(l)}$	lgK_p=-pH; pH=6,7
14	$H_2AsO^-_{3(l)}+H_2O_{(l)}=HAsO_4^{2-}{}_{(l)}+3H^+_{(l)}+2\bar{e}$	E=0,585-0,088pH
15	$As_{(s)}+3H_2O_{(l)}=H_2AsO^-_{3(l)}+4H^+_{(l)}+3\bar{e}$	E=0,41+0,02lg[$H_2AsO_3^-$]-0,08pH
16	$As_{(s)}+3H_2O_{(l)}=H_3AsO_{3(l)}+3H^+_{(l)}+3\bar{e}$	E=0,23+0,02lg[H_3AsO_3]-0,06pH
17	$AsH_{3(g)}=As_{(s)}+3H^+_{(l)}+3\bar{e}$	E=-0,627-0,059pH
18	$H_3AsO_{3(l)}+H_2O_{(l)}=HAsO_4^{2-}{}_{(l)}+4H^+_{(l)}+2\bar{e}$	E=0,858-0,118pH
19	$H_3AsO_{3(l)}=H_2AsO^-_{3(l)}+H^+_{(l)}$	lgK_p=-pH; pH=9,2
20	$H_3AsO_{4(l)}=H_2AsO^-_{4(l)}+H^+_{(l)}$	lgK_p=-pH; pH=2,2
21	$Mn^{2+}{}_{(l)}+2H_2O_{(l)} = MnO_{2(s)}+4H^+_{(l)}+2\bar{e}$	E=1,258-0,118pH
22	$Mn_2O_{3(s)}+H_2O_{(l)} = 2MnO_{2(s)}+2H^+_{(l)}+2\bar{e}$	E=1,014-0,059pH
23	$2Mn^{2+}{}_{(l)}+3H_2O_{(l)} = Mn_2O_{3(s)}+6H^+_{(l)}+2\bar{e}$	E=1,502-0,177pH
24	$3Mn^{2+}{}_{(l)}+4H_2O_{(l)} = Mn_3O_{4(s)}+8H^+_{(l)}+2\bar{e}$	E=1,912-0,236pH
25	$2Mn_3O_{4(s)} + H_2O_{(l)}=3Mn_2O_{3(s)}+2H^+_{(l)}+2\bar{e}$	E=0,689-0,059pH
26	$3Mn(OH)_{2(s)}=Mn_3O_{4(s)}+2H_2O_{(l)}+2H^+_{(l)}+2\bar{e}$	E=0,402-0,059pH
27	$Mn^{2+}{}_{(l)}+2H_2O_{(l)} = Mn(OH)_{2(s)}+2H^+_{(l)}$	lgK_p=-lg[Mn^{2+}]-2pH; pH=8
28	$Mn(OH)_{2(s)}=HMnO^-_{2(l)}+H^+_{(l)}+2\bar{e}$	lgK_p=lg[$HMnO_2^-$]-pH; pH=13
29	$3HMnO^-_{2(l)}+H^+_{(l)}=Mn_3O_{4(s)}+2H_2O_{(l)}+2\bar{e}$	E=1,317+0,295pH
30	$3Mn^{2+}{}_{(l)}+H_2AsO_4^{2-}{}_{(l)}+8H_2O_{(l)}==Mn_3(AsO_4)_2\cdot 8H_2O_{(s)}+4H^+_{(l)}$	lgK_p=4-4pH; pH=3,4
31	$3Mn^{2+}{}_{(l)}+H_3AsO_{3(l)}+10H_2O_{(l)}==Mn_3(AsO_4)_2\cdot 8H_2O_{(s)}+10H^+_{(l)}+4\bar{e}$	E=0,7817
32	$3Mn(OH)_{2(s)}+2As_{(s)}+10H_2O_{(l)}==Mn_3(AsO_4)_2\cdot 8H_2O_{(s)}+10H^+_{(l)}+10\bar{e}$	E=0,1826-0,0595pH
33	$3Mn_2O_{3(s)}+4HAsO_4^{2-}{}_{(l)}+7H_2O_{(l)}==2Mn_3(AsO_4)_2\cdot 8H_2O_{(s)}+2H^+_{(l)}+10\bar{e}$	E=-0,904-0,0118pH
34	$Mn_3(AsO_4)_2\cdot 8H_2O_{(s)}=Mn_3O_{4(s)}+2AsO_4^{3-}{}_{(l)}++4H_2O_{(l)}+8H^+_{(l)}+2\bar{e}$	E=2,59-0,236pH
35	$3Mn(OH)_{2(s)}+2AsO_4^{3-}{}_{(l)}+2H_2O_{(l)}+6H^+_{(l)}=Mn_3(AsO_4)_2\cdot 8H_2O_{(s)}$	lgK_p=-2lg[AsO_4^{3-}]+6pH; pH=12,5
36	$Mn_3(AsO_4)_2\cdot 8H_2O_{(s)}=3Mn(OH)_{2(s)}+2HAsO_3^{2-}{}_{(l)}+4H_2O_{(l)}$	E=-0,552
37	$3Mn^{2+}{}_{(l)}+2As_{(s)}+16H_2O_{(l)}==Mn_3(AsO_4)_2\cdot 8H_2O_{(s)}+16H^+_{(l)}+10\bar{e}$	E=0,466-0,0944pH

All reactions (from 21 to 29 in Table I) of Mn-H_2O system are indicated by solid lines, which shows the interaction and the area of existence of manganese ions: Mn^{2+}, $HMnO_2^-$ oxides and manganese hydroxide Mn_2O_3, Mn_3O_4, MnO_2, $Mn(OH)_2$. Reaction equations numbered from 30 to 37 in Table I correspond to the area of existence of manganese arsenate composition $Mn_3(AsO_4)_2\cdot 8H_2O$, the boundaries of which are marked by solid bold lines of manganese arsenate $Mn_3(AsO_4)_2\cdot 8H_2O$ occupies an area of stability in the pH range from 3.45 (line 30) to 12.5 (line 35) and the value of the redox potential from -0.52 V (lines 32, 35, 36) to + 0.77 V (line 30, 33). This composition of manganese arsenate is stable in wide range, but under standard conditions in highly acidic environment (pH <3.45) and in highly alkaline environment (pH> 12.5).

On Fig. 2, for the first time diagram of E-pH system of Mn-Sb-H_2O under standard conditions by combining private Sb-H_2O system diagram with private diagram of Mn-H_2O system is shown.

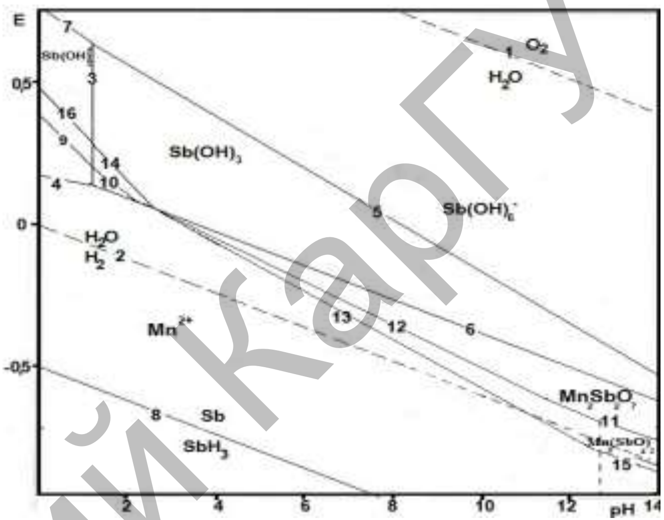

Fig. 2 Diagram of E-pH system of Mn-Sb-H_2O

The first two equations are the reactions of the upper and lower boundaries of water sustainability. The following reaction under 3 to 8 numbers of Table II correspond to all possible interactions of Sb-H_2O system, showing the interaction region and the existence of dissolved antimony: $Sb(OH)_2^+$, $Sb(OH)_3$, $Sb(OH)_6^-$, also SbH_3 and Sb^0.

TABLE II

System interaction equations Mn-Sb-H_2O

№	Chemical reaction	Electrode reaction
1	$H_2O_{(l)}=O_{2(g)}+4H^+_{(l)}+4\bar{e}$	E=1,23-0,059pH
2	$H_{2(g)}=2H^+_{(l)}+2\bar{e}$	E=-0,059pH
3	$Sb(OH)_2^+{}_{(l)} + H_2O_{(l)}= Sb(OH)_{3(s)}+H^+_{(l)}$	pH=2,17
4	$Sb_{(s)} +2H_2O_{(l)}= Sb(OH)_2^+{}_{(l)}+2H^+_{(l)}+3\bar{e}$	E=0,002 -0,039pH
5	$Sb(OH)_{3(s)}+ 3H_2O_{(l)}= Sb(OH)_6^-{}_{(l)} +3H^+_{(l)}+2\bar{e}$	E=0,611-0,089pH
6	$Sb_{(s)}+ 3H_2O_{(l)}= Sb(OH)_{3(s)}+3H^+_{(l)}+3\bar{e}$	E=0,222 -0,059pH
7	$Sb(OH)_2^+{}_{(l)} +4H_2O_{(l)}= Sb(OH)_6^-{}_{(l)}+4H^+_{(l)}+2\bar{e}$	E=0,729 -0,118pH
8	$SbH_{3(g)}= Sb_{(g)}+3H^+_{(l)}+3\bar{e}$	E=-0,53$_3$-0,059 pH
9	$2Mn^{2+}{}_{(l)}+2Sb(OH)_2^+{}_{(l)}+3H_2O_{(l)}=Mn_2Sb_2O_{7(s)}+10H^+_{(l)}+4\bar{e}$	E=0,4075-0,148
10	$2Mn^{2+}{}_{(l)}+2Sb(OH)_{3(s)}+H_2O_{(l)}=Mn_2Sb_2O_{7(s)}+8H^+_{(l)}+4\bar{e}$	E=0,3813-0,118pH
11	$2Sb_{(s)} +3H_2O_{(l)}+2HMnO_2^-{}_{(l)}=Mn_2Sb_2O_{7(s)}+8H^+_{(l)}+10\bar{e}$	E=-0,128-0,472pH
12	$2Sb_{(s)}+2Mn^{2+}{}_{(l)}+7H_2O_{(l)}=Mn_2Sb_2O_{7(s)}+14H^+_{(l)}+10\bar{e}$	E=-0,2858-0,826pH
13	$2Sb_{(s)}+3Mn^{2+}{}_{(l)}+8H_2O_{(l)}=Mn_3(SbO_4)_{2(s)}+16H^+_{(l)}+10\bar{e}$	E=0,325-0,0944pH
14	$2Sb(OH)_{3(s)}+3Mn^{2+}{}_{(l)}+2H_2O_{(l)}=Mn_3(SbO_4)_{2(s)}+10H^+_{(l)}+4\bar{e}$	E=0,479-0,148pH
15	$2Sb_{(s)}+3HMnO_2^-{}_{(l)}+2H_2O_{(l)}=Mn_3(SbO_4)_{2(s)}+7H^+_{(l)}+10\bar{e}$	E=-0,285-0,041pH
16	$3Mn^{2+}{}_{(l)}+2Sb(OH)_2^+{}_{(l)}+4H_2O_{(l)}=Mn_3(SbO_4)_{2(s)}+12H^+_{(l)}+4\bar{e}$	E=1,738-0,177pH

Equations numbered from 9 to 16 in Table II correspond to the reactions of formation of various manganese antimonates (built based on Sb-H_2O and Mn-H_2O systems), in particular, the equations 9, 10, 11, 12 – borders of manganese antimonate stability of $Mn_2Sb_2O_7$ composition; equations 13, 14, 15, 16 - the stability limits of manganese antimonate of $Mn_3(SbO_4)_2$ composition.

An analysis of the E-pH diagram of Mn-Sb-H_2O system found that manganese antimonates compounds in oxidized, reducing aqueous media throughout the pH range at 25 ° C and 1 atm are stable.

On Fig. 3, for the first time diagram of E-pH system of Mn-Bi-H_2O under standard conditions by combining private Bi-H_2O system diagram with of a private diagram of Mn-H_2O is shown. On E-pH diagram, line 1, 2 correspond to the upper and lower boundaries of water sustainability.

Reaction equations of Bi-H_2O system (numbered from 3 to 12 in Table III), indicated in the diagram by dotted lines correspond to all the possible interactions of the Bi-H_2O system, which shows the interaction and the existence region of bismuth ions: Bi^0, Bi^{3+}, $BiOH^{2+}$, and bismuth oxides Bi_2O_3, Bi_4O_7, Bi_2O_4, Bi_2O_5, and also BiH_3.

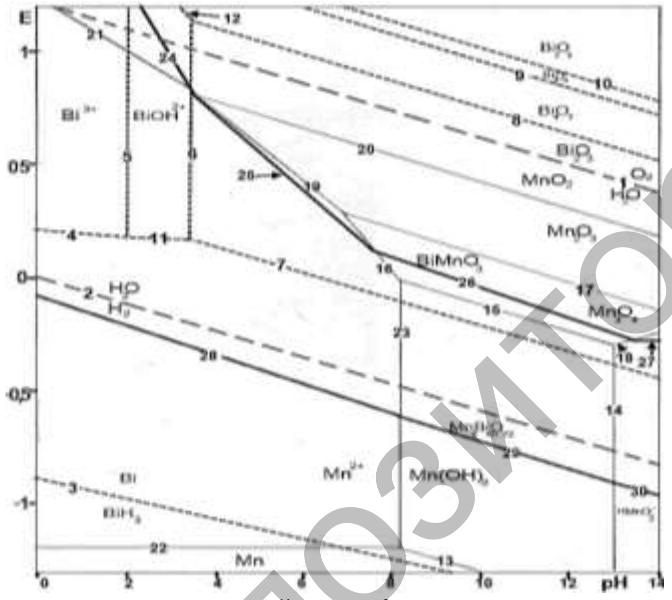

Fig.3 E-pH diagram of Mn-Bi-H_2O

The following reaction equations (from 13 to 23 in Table III) of Mn-H_2O system are indicated by thin solid lines, by which the interaction and the domain of existence of manganese ions are shown: Mn^{2+}, $HMnO_2^-$ oxides and manganese hydroxide Mn_2O_3, Mn_3O_4, MnO_2, $Mn(OH)_2$.

The equations numbered from 24 to 30 in Table III correspond to the region of existence of bismuth manganese compounds (built based on Bi-H_2O and Mn-H_2O systems), in particular the reactions under 28, 29, 30 numbers show the area of formation of manganese bismuthate composition $Mn_8Bi_{40}O_{72}$, and the lines 24, 25, 26, 27 - $BiMnO_3$ compound composition (stability area of the compounds is not limited in the considered anode region), the possibility of synthesizing these compounds as solid phased, and also with hydrochemical methods is confirmed with known literature data [1], [2].

Compounds such as $Bi_2Mn_4O_9$, $Bi_3Mn_5O_{12}$ considering limiting interactions of the Bi-H_2O and Mn-H_2O systems were unable to reflect on this diagram.

TABLE III

SYSTEM INTERACTION EQUATIONS MN-BI-H_2O SYSTEM

№	Chemical reaction	Electrode reaction
1	$H_2O_{(l)}=O_{2(g)}+4H^+_{(l)}+4\bar{e}$	E=1,23-0,059pH
2	$H_{2(g)}=2H^+_{(l)}+2\bar{e}$	E=-0,059pH
3	$BiH_{3(g)}=Bi_{(s)}+3H^+_{(l)}+3\bar{e}$	E=0,8197-0,0591pH
4	$Bi_{(s)}=Bi^{3+}_{(l)}+3\bar{e}$	$E=0,22+0,02lg[Bi^{3+}]$
5	$Bi^{3+}_{(l)}+H_2O_{(l)}=BiOH^{2+}_{(l)}+H^+_{(l)}$	pH=2
6	$2BiOH^{2+}_{(l)}+H_2O_{(l)}=Bi_2O_{3(s)}+4H^+_{(l)}$	$lg[BiOH^{2+}]=6-2pH$
7	$2Bi_{(s)}+3H_2O_{(l)}=Bi_2O_{3(s)}+6H^+_{(l)}+6\bar{e}$	E=0,371-0,0591pH
8	$2Bi_2O_{3(s)}+H_2O_{(l)}=Bi_4O_{7(s)}+2H^+_{(l)}+2\bar{e}$	E=1,338-0,0591pH
9	$2Bi_4O_{7(s)}+H_2O_{(l)}=2Bi_2O_{4(s)}+2H^+_{(l)}+2\bar{e}$	E=1,541-0,0591pH
10	$Bi_2O_{4(s)}+H_2O_{(l)}=Bi_2O_{5(s)}+2H^+_{(l)}+2\bar{e}$	E=1,607-0,0591pH
11	$Bi_{(s)}+H_2O_{(l)}=BiOH^{2+}_{(l)}+H^+_{(l)}+3\bar{e}$	E=0,234-0,0197pH
12	$4BiOH^{2+}_{(l)}+3H_2O_{(l)}=Bi_4O_{7(s)}+10H^+_{(l)}+2\bar{e}$	E=2,16-0,2295pH-
13	$Mn_{(s)}+2H_2O_{(l)}=Mn(OH)_{2(s)}+2H^+_{(l)}+2\bar{e}$	E=-0,727-0,059pH
14	$Mn(OH)_{2(s)}=HMnO^-_{2(l)}+H^+_{(l)}+2\bar{e}$	pH=12,9
15	$3Mn(OH)_{2(s)}=Mn_3O_{4(s)}+2H_2O_{(l)}+2H^+_{(l)}+2\bar{e}$	E=0,402-0,059pH
16	$3Mn^{2+}_{(l)}+4H_2O_{(l)}=Mn_3O_{4(s)}+8H^+_{(l)}+2\bar{e}$	E=1,912-0,236pH
17	$2Mn_3O_{4(s)}+H_2O_{(l)}=3Mn_2O_{3(s)}+2H^+_{(l)}+2\bar{e}$	E=0,689-0,059pH
18	$3HMnO^-_{2(l)}+H^+_{(l)}=Mn_3O_{4(s)}+2H_2O_{(l)}+2\bar{e}$	E=1,317+0,295pH
19	$2Mn^{2+}_{(l)}+3H_2O_{(l)}=Mn_2O_{3(s)}+6H^+_{(l)}+2\bar{e}$	E=1,502-0,177pH
20	$Mn_2O_{3(s)}+H_2O_{(l)}=2MnO_{2(s)}+2H^+_{(l)}+2\bar{e}$	E=1,014-0,059pH
21	$Mn^{2+}_{(l)}+2H_2O_{(l)}=MnO_{2(s)}+4H^+_{(l)}+2\bar{e}$	E=1,258-0,118pH
22	$Mn_{(s)}=Mn^{2+}_{(l)}+\bar{e}$	E=-1,209
23	$Mn^{2+}_{(l)}+2H_2O_{(l)}=Mn(OH)_{2(s)}+2H^+_{(l)}$	$lgK_p=-lg[Mn^{2+}]-2pH$
24	$Mn^{2+}_{(l)}+BiOH^{2+}_{(l)}+2H_2O_{(l)}==BiMnO_{3(s)}+5H^+_{(l)}+\bar{e}$	E=0,225-00,072pH
25	$2Mn^{2+}_{(l)}+Bi_2O_{3(s)}+3H_2O_{(l)}=2BiMnO_{3(s)}+6H^+_{(l)}+2\bar{e}$	E=0,225-00,072pH
26	$2Mn_3O_{4(s)}+3Bi_2O_{3(s)}+H_2O_{(l)}=6BiMnO_{3(s)}+2H^+_{(l)}+2\bar{e}$	E=0,225-00,072pH
27	$2HMnO^-_{2(l)}+Bi_2O_{3(s)}=2BiMnO_{3(s)}+H_2O_{(l)}+2\bar{e}$	E=0,225-00,072pH
28	$8Mn^{2+}_{(l)}+40Bi_{(s)}+72H_2O_{(l)}=Mn_8Bi_{40}O_{72(s)}+$ $+144H^+_{(l)}+128\bar{e}$	E=0,25-00,072pH
29	$8Mn(OH)_{2(s)}+40Bi_{(s)}+56H_2O_{(l)}=Mn_8Bi_{40}O_{72(s)}$ $+128H^+_{(l)}+128\bar{e}$	E=0,5-00,072pH
30	$8HMnO^-_{2(l)}+40Bi_{(s)}+56H_2O_{(l)}=Mn_8Bi_{40}O_{72(s)}+120H^+_{(l)}+128\bar{e}$	E=0,225-00,072pH

An analysis of the E-pH diagram of Mn-Bi-H_2O system found that bismuthcontaining manganese compounds are stable throughout the whole pH range, wherein $BiMnO_3$ – in oxidized, $Mn_8Bi_{40}O_{72}$ - in oxidized and in recovering aqueous environment at 25°C and 1 atm.

III. CONCLUSION

Accordingly, based on thermodynamic analysis using E-pH diagrams can it may be stated that arsenates, antimonates, and manganese bismuthate are stable compounds in acid environment at 25° C and 1 atm. The practical value of these studies will be tested in laboratory experiments to clean copper electrolyte from arsenic, antimony and bismuth manganese-containing precipitators.

REFERENCES

[1] Atou T., Chiba H., Ohoyama K., Yamaguchi Y., SyonoY., Structure determination of ferromagnetic perovskite //Solid State Chem. – 1999; 145, P.639-642.
http://dx.doi.org/10.1006/jssc.1999.8267

[2] W.-K. Tarasenko T.N., Kravchenko Z.F., Kamenev V.I., Galyas A.I., Demidenko O.F., Ignatenko O.V., Makovecky G.I., Yanushkevich K.I. The crystal structure and magnetic properties of nanoscale powders and films of multiferroic $BiMnO_3$: the effect of pressure and replacing with lanthanum // Physics and High Pressure Equipment 2010, N.20, №4, pp. 70-79.

http://dx.doi.org/10.15242/IICBE.C0816212