ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ
Қ. И. Сәтпаев атындағы Қазақ ұлттық техникалық зерттеу университеті

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Казахский национальный исследовательский
технический университет им. К. И. Сатпаева

N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN
Kazakh national research technical university
named after K. I. Satpayev

SERIES
OF GEOLOGY AND TECHNICAL SCIENCES

1 (433)

JANUARY – FEBRUARY 2019

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы "ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы" ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

«ҚР ҰҒА Хабарлары. Геология мен техникалық ғылымдар сериясы».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Меншіктенуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).
Қазақстан республикасының Мәдениет пен ақпарат министрлігінің Ақпарат және мұрағат комитетінде 30.04.2010 ж. берілген **№10892-Ж** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Мерзімділігі: жылына 6 рет.
Тиражы: 300 дана.

Редакцияның мекенжайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., 220, тел.: 272-13-19, 272-13-18,
http://www.geolog-technical.kz/index.php/en/

Редакцияның мекенжайы: Қазақстан, 050010, Алматы қ., Қабанбай батыра көш., 69а.
Қ. И. Сәтбаев атындағы геология ғылымдар институты, 334 бөлме. Тел.: 291-59-38.

Типографияның мекенжайы: «Аруна» ЖК, Алматы қ., Муратбаева көш., 75.

«Известия НАН РК. Серия геологии и технических наук».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан (г. Алматы)
Свидетельство о постановке на учет периодического печатного издания в Комитете информации и архивов Министерства культуры и информации Республики Казахстан **№10892-Ж,** выданное 30.04.2010 г.

Периодичность: 6 раз в год
Тираж: 300 экземпляров

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, ком. 219, 220, тел.: 272-13-19, 272-13-18, http://nauka-nanrk.kz /geology-technical.kz

---

Адрес редакции: Казахстан, 050010, г. Алматы, ул. Кабанбай батыра, 69а.
Институт геологических наук им. К. И. Сатпаева, комната 334. Тел.: 291-59-38.

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Owner: RPA "National Academy of Sciences of the Republic of Kazakhstan" (Almaty)
The certificate of registration of a periodic printed publication in the Committee of information and archives of the Ministry of culture and information of the Republic of Kazakhstan N 10892-Ж, issued 30.04.2010

Periodicity: 6 times a year
Circulation: 300 copies

Editorial address: 28, Shevchenko str., of. 219, 220, Almaty, 050010, tel. 272-13-19, 272-13-18,
http://nauka-nanrk.kz/geology-technical.kz

Editorial address: Institute of Geological Sciences named after K.I. Satpayev
69a, Kabanbai batyr str., of. 334, Almaty, 050010, Kazakhstan, tel.: 291-59-38.

Address of printing house: ST "Aruna", 75, Muratbayev str, Almaty

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 98 – 106 **https://doi.org/10.32014/2019.2518-170X.12**

UDC 669.15-198

V. M. Shevko[1], D. K. Aitkulov[2], D. D. Amanov[1], A. D. Badikova[1], M. A. Tuleyev[1]

[1]M. Auezov South Kazakhstan State University, Shymkent, Kazakhstan,
[2]Institute of geological sciences named after K. I. Satpaev, Satbayev University, Almaty, Kazakhstan.
E-mail: shevkovm@mail.ru, dos.ait.58@mail.ru, loken666@mail.ru, sunstroke_91@mail.ru,
mustafa19930508@mail.ru

THERMODYNAMIC MODELLING CALCIUMCARBIDE AND A FERROALLOY FORMATION FROM A SYSTEM OF THE DAUBABA DEPOSIT BASALT – CARBON – IRON

Abstract. The present article contains results ofthermodynamic modelling the temperature (from 900 to 2500°C) and iron content (from 0 to 8%) effect on interaction of the Daubaba deposit basalt (40,88% of SiO_2, 19,58% of CaO, 13,36% of Al_2O_3, 15,25% of FeO, 6,68% of MgO, 1,74% of Na_2O, 0,98% of TiO_2, 0,41% of MnO, 0,55% of SO_2) with carbon and formation of calcium carbide and a complex silicon and aluminium-containing ferroalloy. The investigation has been fulfilled using a software package HSC-5.1 based on a Gibbs energy minimum. It was found, that transition degree of calcium into CaC_2 at 2000^0C and 45% of C at increase in iron content from 0 to 8% decreases from 54,6% to 42,4%, and transition degree of silicon into the alloy increases and makes 88,1%. Silicon and aluminiumconcentration in the alloy and the calcium carbide capacity decrease at increase in iron quantity.87,4-89% of silicon and 50-52% of calcium can be extracted into the alloy and calcium carbide respectively from the basalt in the presence of 45% of carbon, 0-1,9% of ironand temperature of $2028\text{-}2043^0$C. The ferroalloy formed contains 55-56% of Σ(Si+Al);the calcium carbide is characterised by capacity of 240-248 l/kg. The alloy containing silicon and aluminium is a complex ferroalloy – ferrosilicoaluminium of a FS45Al5 grade; the calcium carbide is related to 2-3 grades.

Keywords: basalt, reduction, carbon, temperature, thermodynamic modelling, calcium carbide, ferroalloy.

At present calcium carbide is produced in electric furnaces out of lime and coke at temperature of 1900-2100°C according to the reaction:

$$CaO + 3C = CaC_2 + CO. \quad (1)$$

The process is characterised by electric energy consumption of 2980-3350 kW·h per 1 t of calcium carbide [1, 2]. A siliceous ferroalloy is obtained at 1600-1800°C from quartz-containing raw materials by a carbothermal way in ore-thermalfurnaces. This process is characterized by power consumption from 2200 to 4750 kW·h per 1 t of a ferroalloy (depending onsilicon content in it, which changes from 25 to 45%) [3-5]. At the calcium carbide production thermal and electric losses make to 14% from the maximum power [1], and at the siliceous ferroalloy manufacture these losses make 11-14% [6]. Combination of both these processes in one electric furnace permits to reduce the thermal losses in 2 times. The combined processes have been developed for chloride sublimation of off-grade oxide ores [7-9] and processing of oxidized zinc-containing ores [10, 11]. Simultaneous production of calcium carbide and a siliceous ferroalloy may be realized from the raw materials containing SiO_2 and CaO. This raw material group includes 64,1 million tonne of Kazakhstan basalts (Daubabadeposit (19,4 m. t), Tashkursay (15,7 m. t), Dormensay (5,9 m. t), Karauzek (5,7 m. t), Kozyrevsky (3,8 m. t), Chernaya Mazarka (2,8 m. t), Dubersay (10,8 m. t)) [12]. The basalts contain 39-43% of SiO_2, 18-21% of CaO, 12-15% of Al_2O_3, 14-17% of FeO. Now these basalts are mainly used for manufacture of a fibre and a cast stone material [13], which technology is constantly improved [14-17], and also for manufacture of other production [18]. Being used the program HSC-5.1 (Reaction Equations subprogram) [19] we have preliminary calculated ΔG and found that a condition ΔG=0 for joint reduction of Ca, Si, Al oxides on the reactions

$$CaO + 2SiO_2 + Al_2O_3 + Fe2O_3 + 15C = CaC_2 + 2FeSi + 2Al + 13CO; \quad (2)$$

$$CaO + SiO_2 + Al_2O_3 + Fe + 8C = CaC_2 + FeSi + 2Al + 6CO; \quad (3)$$

is satisfied at 1738and 2092K respectively (table 1).

Table 1 – Temperature effect on ΔG (kJ) for the reactions of joint carbothermal reduction of the oxides

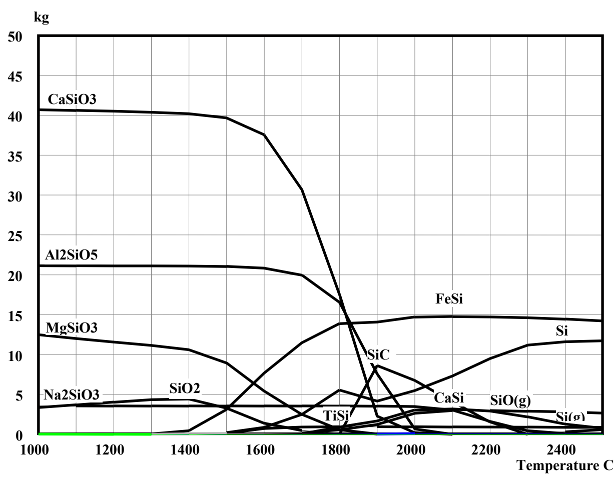
Reaction	Temperature, K								
	1173	1373	1673	1738	1773	1873	2073	2092	2173
2	1123,0	724,1	132,3	0	-71,0	-274,6	-679,3	-716	-879,8
3	1057,7	827,9	486,4	429,1	369,7	253,3	22,6	0	-91,9

Studying the possibility of simultaneous production calcium carbide and a silicon and aluminium-containing ferroalloy out of the Daubaba basalt comprising 40,88% of SiO_2, 19,58% of CaO, 13,36% of Al_2O_3, 15,25% of FeO, 6,68% of MgO, 1,74% of Na_2O, 0,98% of TiO_2, 0,41% of MnO, 0,55% of SO_2 has been realized by us by means of thermodynamic modelling with use of the HSC-5.1 software package, in particular the Equilibrium Composition subprogram [19]. The Daubababasalt initial weight was 100 kg. Calculation of the equilibrium is made on the basis of a Gibbs energy minimum principle taking into consideration activities of substances. The developers of the HSC-5.1 program have based on an ideology of a SGTE consortium (Scientific Group Thermodata Europe) which develops, supports and distributes the high-quality databases intended for calculation of an equilibrium composition of chemically reacting systems. The SGTE structure includes specialized scientific centers in Germany, Canada, France, Sweden, the Great Britain and the USA [20]. The error of the calculations made by means of the HSC-5.1 program makes no more than 4-6%.

Thermodynamic modelling influence of temperature (from 1000 to 2300^{0}C) and iron content (from 0 to 8% from the basalt weight) (at 45% of carbon from the basalt weight) on the equilibrium silicon distribution degree in a system of Daubababasalt (DB) – carbon – iron was carried out at pressure of 0,1MPa. The results of quantitative distribution of the silicon and calcium-containing substances are represented in figures 1 and 2.

Judging by the figures, silicon and calcium in the system are as $CaSiO_3$, Al_2SiO_5, $MgSiO_3$, TiO_2, SiO_2, FeSi, Fe_3Si, TiSi, CaSi, Si and SiO_{gas}, CaO, CaC_2, Ca_{gas}, and aluminium as Al_2SiO_5, Al_2O_3 and Al. The information about the initial temperature of formation of the compounds (T_i, ^{0}C) is given in table 2.

A



B

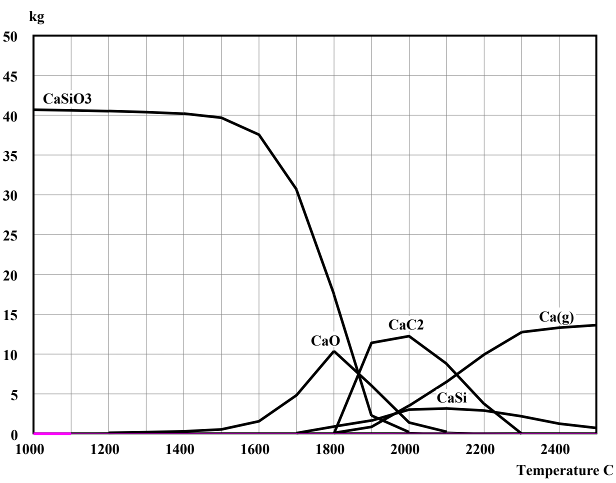


Figure 1 – Temperature effect on quantitative distribution of the Si and Ca containing substances
in the system of DB-45%Cat absence of iron:
A – silicon-containing substances, B – calcium-containing substances

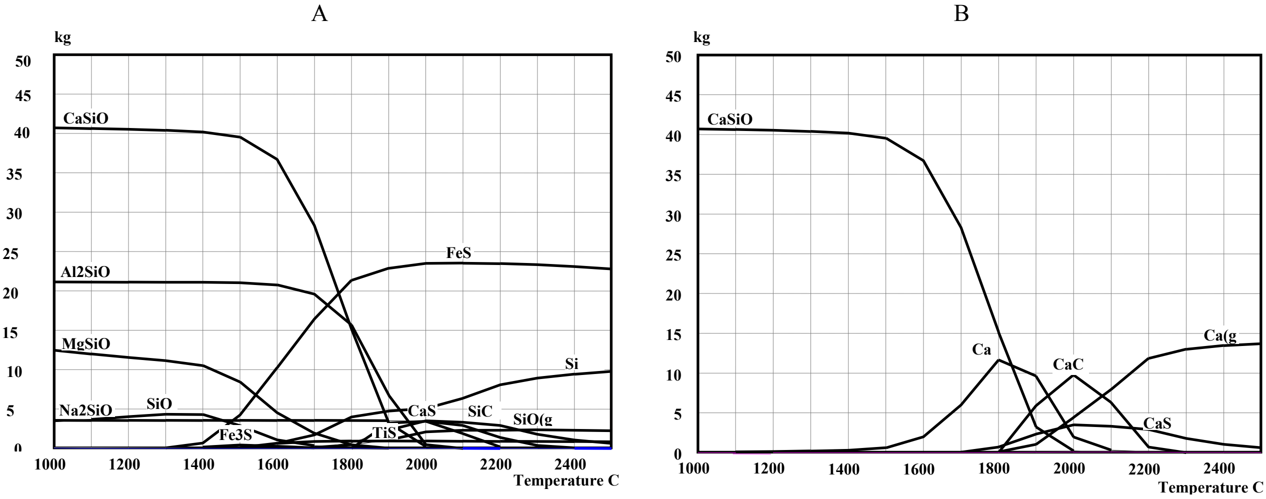


Figure 2 – Temperature effect on quantitative distribution of the Si and Ca containing substances
in the system of DB-45%C at presence of 8% of iron:
A – silicon-containing substances, B – calcium-containing substances

Table 2 – Initial formationtemperature(T_i, ^0C)

Substances	SiC	TiSi	CaSi	Si	CaC_2	Ca_{gas}	Al	Fe_3Si	SiO_{gas}	FeSi
T_i, ^0C (8% of Fe)	1900	1500	1700	1400	1800	1800	1700	1300	1500	1300

As follows from the table 2 the simultaneous formation of a ferroalloy on the basis of FeSi, Fe_3Si, TiSi, Si, SiC, CaSi, Al occurs at temperature above 1800^0C.

The calculation results of equilibrium transition degree (α, %) of Siand Al into the alloy (αSi (alloy) and αAl (alloy)) and calcium into calcium carbide (αCa (CaC_2)) depending on temperature and iron amount are represented in figures 3 and 4.

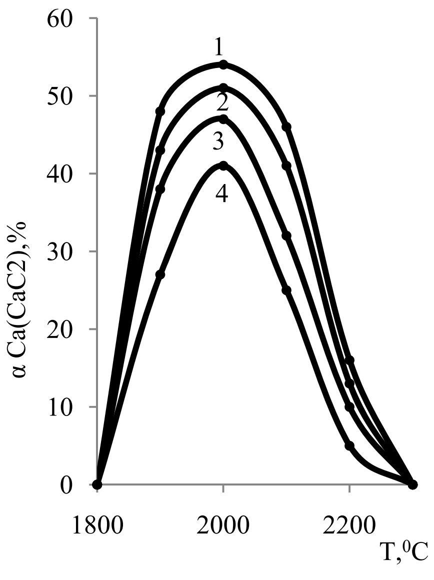


Figure 3 – Temperature and iron content effect onαCa(CaC_2) at 45% of C:
1 – 0% of Fe, 2 – 2% of Fe, 3 – 4% of Fe, 4 – 8% of Fe

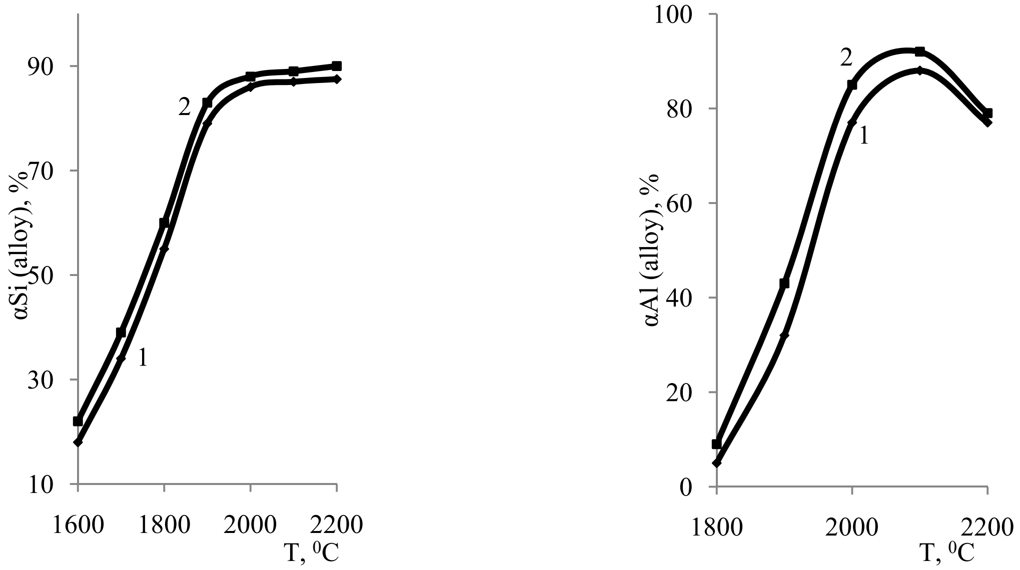


Figure 4 – Temperature and iron content effect onαSi(alloy) andαAl(alloy) at 45% of C: 1 – 0% of Fe, 2 – 8% of Fe

As follows from the figure 3, the increase in iron content from 0 to 8% from the basalt weight (at 45% of C from the basalt weight) decreases α Cainto CaC_2 from 54,6% to 42,4% at 2000^0Caccording to the equation:

$$\alpha Ca(CaC_2) = 54{,}44–1{,}5114\ Fe. \quad (4)$$

The decrease in αCa (CaC_2) at temperatures above 2000^0C can be caused by the CaC_2 decomposition [21]:

$$CaC_2 = Ca_{gas} + 2C. \quad (5)$$

The inverse picture is observed for αSi(alloy) (figure 4). The increase in iron content from 0 to 8% at 45% of C allows to raise αSi (alloy) in the temperature interval of 1600-2000^0C and to achieve 88,1-90,24% at 2000-2200^0C.

An important technological parameter of the developed technology is silicon and aluminium content in the produced ferroalloy (C_{Si}, C_{Al}) and CaC_2 content in the technical carbide (C_{CaC2}). From the figure 5 it

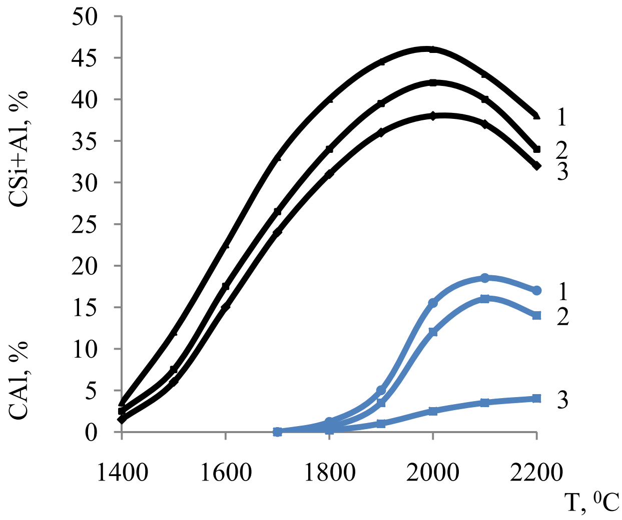


Figure 5 – Temperature and iron content effect on Si and Al content and total Si+Alcontent in the ferroalloy in the system ofDB-20%C-nFe: 1 – 0% of Fe, 2 – 4% of Fe, 3 – 8% of Fe

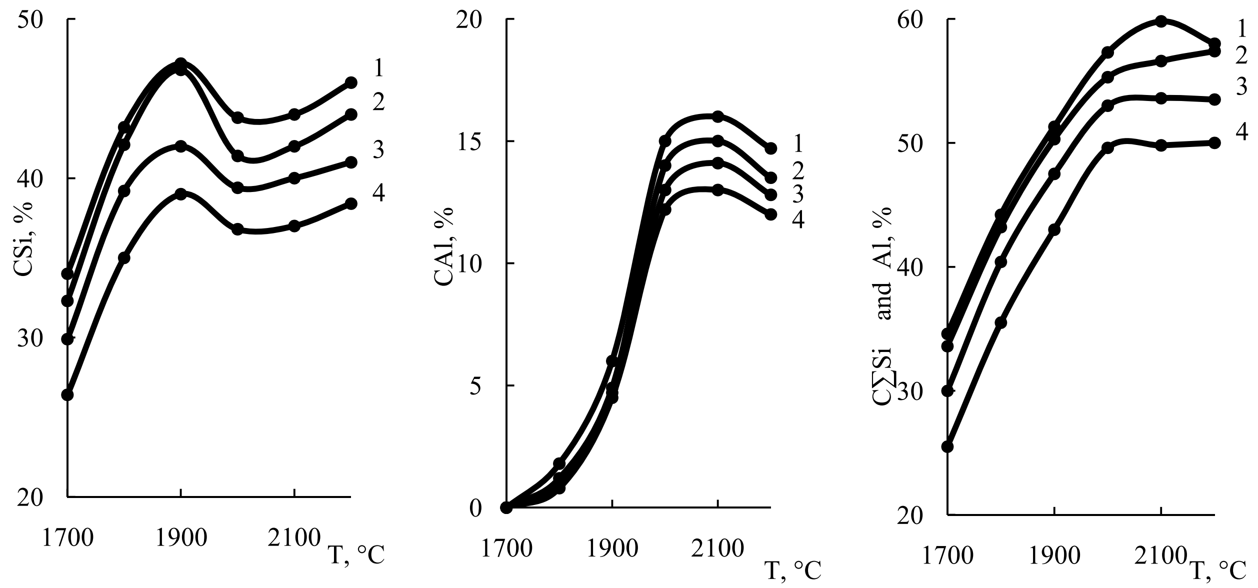


Figure 6 – Temperature and iron content effect on Si and Al content and total Si+Alcontent in the ferroalloy in the system ofDB-45%C-nFe: 1 – 0% of Fe, 2 – 2% of Fe, 3 – 4% of Fe, 4 – 8% of Fe

is obvious, that at 20% of carbon in the system the increase in iron amount from 0 to 8% reduces aluminiumconcentration and total silicon and aluminiumconcentration ($C_{\Sigma Si+Al}$)in an alloy. Maximum $C_{\Sigma Si и Al}$ (45,6%) is reached at 2000^{0}C in absence of iron. With growth of the carbon quantity to 45% the influence pattern of iron on Siand Alconcentration in the alloy does not change. However the pattern of temperature effect on C_{Si} and C_{Al} is a little bit other (figure 6). The increase in temperature to 1900^{0}C raises C_{Si}. Then we see the minimum C_{Si} at 2000-2200^{0}C and its increase at temperature above 2200 ^{0}C. Aluminium contentin the alloy during the temperature growth passes through a maximum at 2100^{0}C and makes13,1% at 8% of Fe. With increase in the temperature the totalSi and Al content in the alloy increases. In the temperature interval of 2000-2200^{0}Cand 2-8% of iron$C_{\Sigma Si+Al}$ makes 49-58%.

The temperature and iron amountinfluence on the calcium carbide capacityis shown in figure 7. As follows from the Figure the iron content increase leads to the capacity reduction. So, if at 2100^{0}C in absence of iron the calcium carbide capacity makes 265 l/kg, then at 8% of Fe it decreases to 244,1 l/kg.

For determination of the optimum temperature and iron amount we have fulfilled researches by a rototablematrix planning method in respect to a bifactorial experiment [22]. The optimization parameters

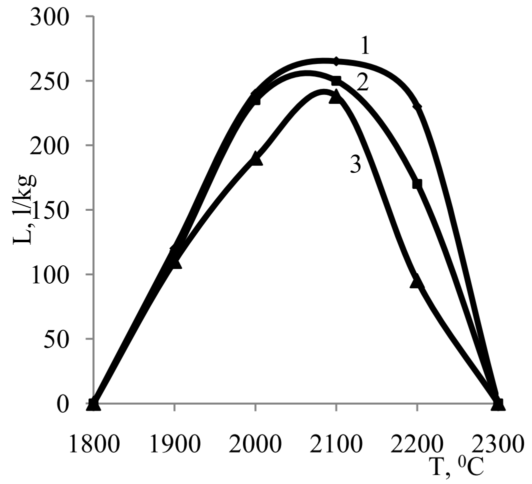


Figure 7 – Temperature and iron content effect on the CaC_2 capacity: 1 – 0% of Fe, 2 – 2% of Fe, 3 – 4% of Fe, 4 – 8% of Fe

are αSi (alloy), αCa (CaC_2), $C_{\Sigma Si+Al}$ in the alloy, calcium carbide capacity L, and independent factors are iron content(from the basalt weight) (Fe, %), temperature (T, ^{0}C). We habe obtained the following regression equations:

$$\alpha Si_{(alloy)} = -1700{,}11 + 1{,}738 \cdot T + 5{,}036 \cdot Fe - 4{,}226 \cdot 10^{-4} \cdot T^2 - 0{,}223 \cdot Fe^2 - 1{,}433 \cdot 10^{-3} \cdot T \cdot Fe \quad (6)$$

$$\alpha_{Ca(CaC2)} = -5904{,}185 + 6{,}018 \cdot T - 14{,}002 \cdot Fe - 1{,}519 \cdot 10^{-3} \cdot T^2 - 0{,}141 \cdot Fe^2 + 6{,}539 \cdot 10^{-3} \cdot T \cdot Fe \quad (7)$$

$$C_{\Sigma Si+Al} = -199{,}967 + 0{,}223 \cdot T - 2{,}764 \cdot Fe - 4{,}8 \cdot 10^{-5} \cdot T^2 - 6{,}964 \cdot 10^{-2} \cdot Fe^2 + 1{,}131 \cdot 10^{-3} \cdot T \cdot Fe \quad (8)$$

$$L_{CaC2} = -28470{,}14 + 27{,}323 \cdot T + 184{,}5 \cdot Fe - 6{,}493 \cdot 10^{-3} \cdot T^2 - 0{,}605 \cdot Fe^2 - 8{,}916 \cdot 10^{-2} \cdot T \cdot Fe \quad (9)$$

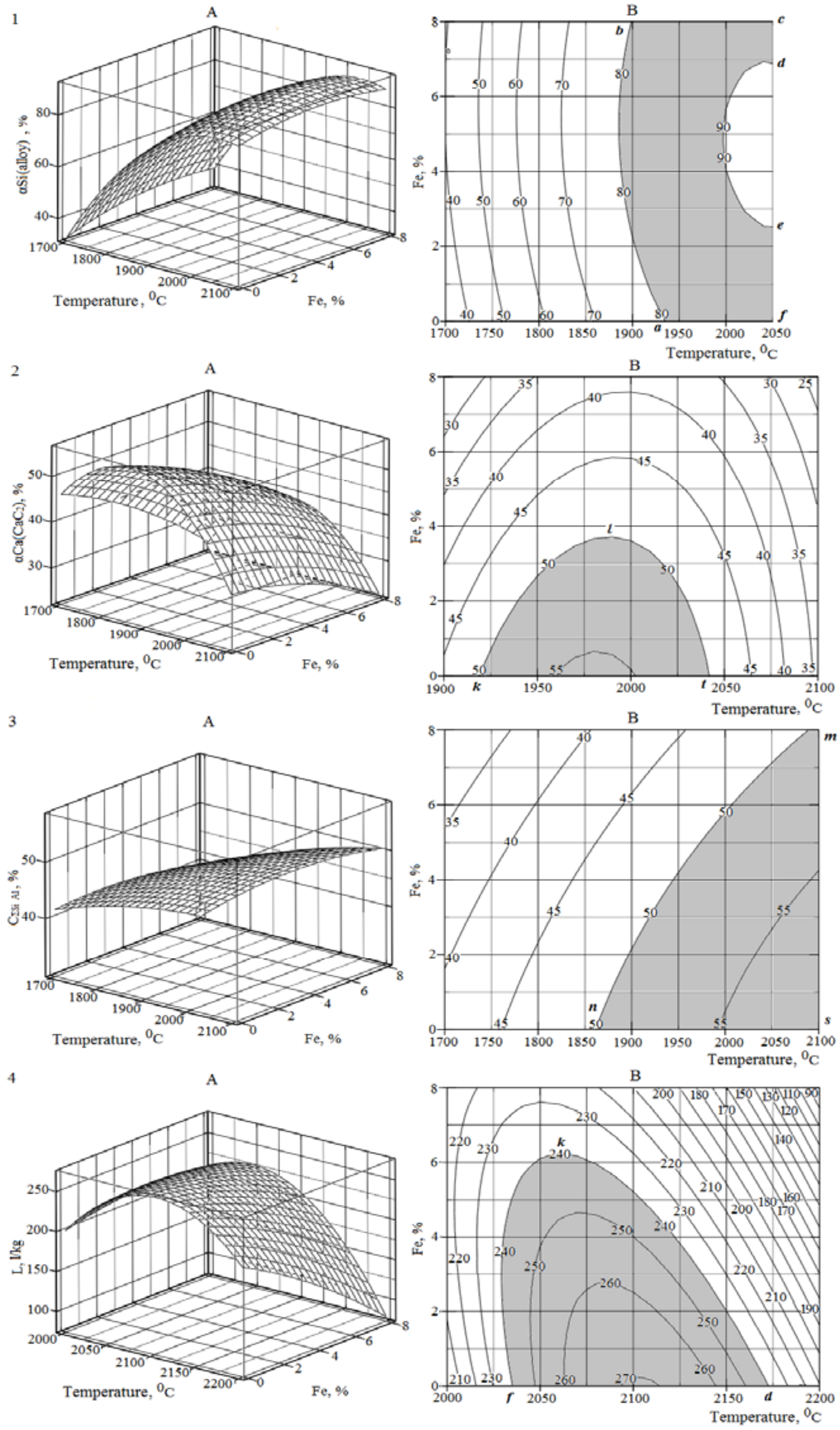


Figure 8 –
Temperature and iron content effect on αSi (alloy) – 1, αCa(CaC_2) – 2, $C_{\Sigma Si+Al}$ – 3 and L – 4 at the Daubaba basalt – carbon interaction. Numerals on the lines – values of a technological parameter, % andl/kg:
A – 3D pictures of response surfaces, B – horizontal sections of the surfaces

Being used the MathCad program [23] on the basis of the equations 6-9 we have constructed response surfaces and their horizontal sections (figure 8). Judging by figure 8, αSi from 80 to 90% is in the area *abcdef* (1880-2050^{0}C and 0-8% of Fe). The extraction degree of Ca into CaC_2 from 50 to 56% is in the area *klt* (1918-2006^{0}C and 0-3,7% of Fe). The total Si and Alcontent in the alloy from 50 to 58% is in the area *nms* (1860-2100^{0}C and 0-4,2% of Fe). The calcium carbide with capacity of 240-271 l/kg is formed in the area *fkd* (2070-2100^{0}C and 0-6,15% of Fe). From figure 8 it is follows, that αCa(CaC_2) is substantially less, than αSi (alloy). Therefore the optimum should be searched proceeding from the maximum αCa (CaC_2). Figure 9 represents the superimposed information about influence of temperature and iron amount on αSi(alloy), αCa (CaC_2), $C_{\Sigma Si+Al}$ in the alloy and capacity L. At the construction the minimum limiting indices were calcium carbide capacity of 240 l/kg (calcium carbide of 2 and 3 grades),αCa (CaC_2) ≥50%, αSi(alloy) ≥87%, $C_{\Sigma Si+Al}$≥55%.

The plane *abcd* in figure 9 is the technological area respective toset limits. Values of temperature and iron content in the border points of the *abcd* area are represented in table 3.

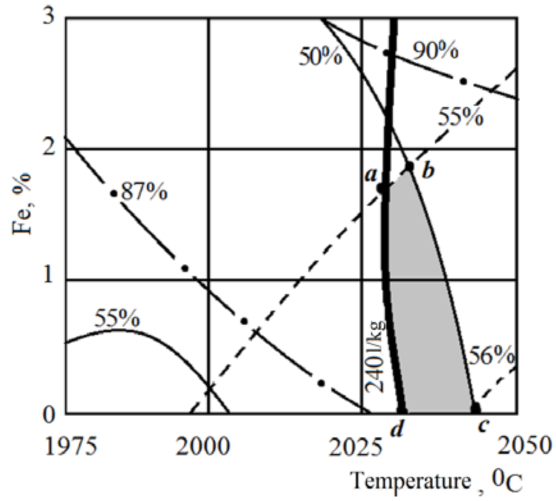


Figure 9 – l Superimposed information about temperature and iron amount effect on αSi(alloy) – (— · — · —), αCa(CaC_2) – (———) , $C_{\Sigma Si+Al}$ (- - - - -) and L (▬▬▬)

Table 3 – Technological parameters in the border points

Point in figure 9	Technological parameter					
	αSi, %	αCa(CaC_2), %	L, l/kg	$C_{\Sigma Si+Al}$	T, ^{0}C	Fe, %
a	88,6	50,8	240	55,0	2028	1,8
b	89,0	50,0	242	55,0	2032	1,9
c	88,0	50,0	248	56,0	2043	0
d	87,4	52,0	240	55,3	2031	0

Thus from the Daubaba basalt at presence of 45% of carbon and 0-1,9% of iron at 2028-2043^{0}Cit can be simultaneously extracted 87,4-89,0% of silicon into the ferroalloy and 50-52% ofcalcium in calcium carbide. In this case thecalcium carbide has capacity of 240-248 l/kg, and the total silicon and aluminium content in the alloy makes 55-56%. Such the alloy concerns to ferrosilicoaluminium ofa FS45Al5 grade[24], and the calcium carbide to 2-3 grade.

Conclusion. On the basis of the results obtained at the thermodynamic modelling the Daubaba basalt – carbon interaction at presence of iron we may draw following conclusions:

- formation of calcium carbide in the system occurs at 1800^{0}C, iron silicides – at 1300^{0}C, silicon and aluminium – at 1400-1700^{0}C;

- transition degree of calcium into CaC_2 at 2000^{0}C and 45% of C at increase in iron content from 0 to 8% decreases from 54,6% to 42,4%, and transition degree of silicon into the alloy increases and makes 88,1%;

- silicon and aluminiumconcentration in the alloy and the calcium carbide capacitydecrease at increase in iron content;

- from the Daubaba basalt at presence of 45% of carbon and 0-1,9% of iron at 2028-2043^{0}C it can be simultaneously extracted 87,4-89,0% of silicon into the ferroalloy and 50-52% of calcium in calcium carbide; the calcium carbide formed has capacity of 240-248 l/kg, and ΣSi+Alin the alloy makes 55-56%;

- thealloy containing silicon and aluminiumis a complex ferroalloy – ferrosilicoaluminium of aFS45Al5 grade, and the calcium carbide formed concerns to 2-3 grade.

The research has been fulfilled under the support of the Ministry of Education and Science of the Republicof Kazakhstan on the basis of grant financing on the theme“Combined technology for production of ferroalloys and calcium carbide from unconventional natural raw material and technogenic formations containing high-clark elements”.

В. М. Шевко[1], Д. К. Айткулов[2], Д. Д. Аманов[1], А. Д. Бадикова[1], М. А. Тулеев[1]

[1]М. Әуезов атындағы Оңтүстік Қазақстан мемлекеттік университеті, Шымкент, Қазақстан,
[2]Қ. И. Сәтбаев атындағы Геологиялық ғылымдар институты, Алматы, Қазақстан

ДАУБАБА КЕНОРНЫНЫҢ БАЗАЛЬТЫ-КӨМІРТЕК-ТЕМІР ЖҮЙЕСІНЕН ФЕРРОҚОРЫТПА ЖӘНЕ КАЛЬЦИЙ КАРБИДІНІҢ ТҮЗІЛУІН ТЕРМОДИНАМИКАЛЫҚ МОДЕЛЬДЕУ

Аннотация. Мақалада Si және Al құрайтын, кешенді ферроқорытпа мен кальций карбидінің түзілуімен көміртегімен Даубаба (40,88% SiO_2, 19,58% CaO, 13,36% Al_2O_3, 15,25% FeO, 6,68% MgO, 1,74% Na_2O, 0,98% TiO_2, 0,41% MnO, 0,55% SiO_2) кенорнының базальтымен әсерлесуіне темір (0-ден 8%-ға дейін) және температураның (1000-ден 2500-ға дейін °С) әсерін термодинамикалық модельденуі бойынша жұмыс қорытындысы келтірілген. Зерттеу Гиббс энергиясының минимумына негізделген, HSC-5.1 кешенді бағдарламаны қолдана отырып жүргізілді. Нәтижесінде 2000 ^{0}С және 45% С, темір мөлшерін 0 ден 8% жоғарылатқанда Са-дің CaC_2 өту дәрежесі 54,6% дан 42,4% -ға төмендейді, ал Si балқымаға өту дәрежесі 88,1% ұлғаяды; темір мөлшерінің артуында балқымадағы Si және Al концентрациясы және кальций карбидінің литражы төмендейді; 45% көміртегі қатысуында базальттан 0-1,9 % Fe және 2028-2043 ^{0}С бір мезетте балқымаға 87,4-89% Si және 50-52% Са кальций карбидіне бөліп алады; түзілген ферроқорытпа 55-56% Σ Si және Al құраса, 242-248 л/кг литражбен кальций карбидімен сипатталады. Si және Al құрамдас балқыма кешенді ферроқорытпаға жатады, яғни ФС45Al5 маркалы ферросиликоалминийге, ал кальций карбиді 2-3 сортқа ие болады.

Түйін сөздер: базальт, қалпына келтіру, көміртек, температура, термодинамикалық модельдеу, кальций карбиді, ферроқорыта.

В. М. Шевко[1], Д. К. Айткулов[2], Д. Д. Аманов[1], А. Д. Бадикова[1], М. А. Тулеев[1]

[1]Южно-Казахстанский государственный университет им. М. Ауэзова, Шымкент, Казахстан,
[2]Институт геологических наук им. К. И. Сатпаева, Алматы, Казахстан

ТЕРМОДИНАМИЧЕСКОЕ МОДЕЛИРОВАНИЕ ОБРАЗОВАНИЯ КАРБИДА КАЛЬЦИЯ И ФЕРРОСПЛАВА ИЗ СИСТЕМЫ БАЗАЛЬТ ДАУБАБИНСКОГО МЕСТОРОЖДЕНИЯ – УГЛЕРОД-ЖЕЛЕЗО

Аннотация. В статье приводятся результаты работы по термодинамическому моделированию влияния температуры (от 900 до 2000°С) и железа (от 0 до 8%) на взаимодействие базальта месторождения Даубаба (40,88% SiO_2, 19,58% CaO, 13,36% Al_2O_3, 15,25% FeO, 6,68% MgO, 1,74% Na_2O, 0,98% TiO_2, 0,41% MnO, 0,55% SO_2) с углеродом с образованием карбида кальция и комплексного ферросплава, содержащего кремний и алюминий. Исследования проводили с использованием программного комплекса HSC-5.1, основанного на минимуме энергии Гиббса. Найдено, что степень перехода кальция в CaC_2 при 2000 ^{0}С и 45%. С при увеличении количества железа от 0 до 8% уменьшается от 54,6% до 42,4%, а степень перехода кремния в сплав возрастает, составляя 88,1%. Концентрация кремния и алюминия в сплаве и литраж карбижа кальция снижаются при увеличении количества железа; в присутствии 45% углерода, 0-1,9 % Fe при 2028-2043 ^{0}С из базальта можно одновременно в сплав извлечь 87,4-89% Si и 50-52% кальция в карбид кальция. Образующийся ферросплав содержит 55-56% $\Sigma_{\text{Si и Al}}$, карбид кальция характеризуется литражом 240-248 л/кг. Сплав, содержащий кремний и алюминий относится к комплексному ферросплаву - ферросиликоалюминию марки ФС45Al5, а карбид кальция обладает 2-3 сортностью.

Ключевые слова: базальт, восстановление, углерод, температура, термодинамическое моделирование, карбид кальция, ферросплав.

Information about authors:

Shevko Viktor Mihajlovich, Doctor of technical sciences, professor of the department of Metallurgy of the South Kazakhstan State University M. Auezov, Shymkent, Kazakhstan; shevkovm@mail.ru; https://orcid.org/0000-0002-9814-6248

Aitkulov Dosmurat Kyzylbievich, deputy director for development of scientific innovation activities and external relations, doctor of technical sciences, professor, institute of Geological Sciences named after K. I. Satpayev, Almaty, Kazakhstan; dos.ait.58@mail.ru; https://orcid.org/0000-0003-2571-6710

Amanov Danijel Daniarovich, Master of technical sciences, specialist of the highest qualification level South Kazakhstan State University named after M. Auezov, Shymkent, Kazakhstan; loken666@mail.ru; https://orcid.org/0000-0002-7379-1910

Badikova Aleksandra Dmitrievna, Master of engineering and technology, junior scientific associate, South Kazakhstan State University named after M. Auezov, Shymkent, Kazakhstan; sunstroke_91@mail.ru; https://orcid.org/0000-0003-0027-4258

Tuleev Mustafa Azatovich, Master of technical sciences, specialist of the highest qualification level South Kazakhstan State University named after M. Auezov, Shymkent, Kazakhstan; mustafa19930508@mail.ru; https://orcid.org/0000-0002-1439-8676

REFERENCES

[1] Ershov V.A. (1984). Electrothermal processes of chemical technology. Chemistry, Leningrad, Russia (in Rus.).

[2] Bogdanov S.P., Kozlov K.B., Lavrov B.A. (2009). Electrothermal processes and reactors. Prospect of Science. St. Petersburg, Russia. ISBN 978-5-903090-32-7 (in Rus.).

[3] Edneral F.P. (1977). Electrometallurgy of steel and ferroalloys. Moscow, Russia (in Rus.).

[4] Gasik M. (2013). Handbook of Ferroalloys: Theory and Technology 1st Edition. Butterworth-Heinemann, USA. ISBN 9780080977539.

[5] Moniz B.J. (2012). Metallurgy. Amer Technical Pub, USA. ISBN 978-0826935229.

[6] Ferroalloys furnace [Electronic resource]. URL:http://lektsii.com/2-67960.html (Date of access: 03.01.2018).

[7] Tleukulov O.M. (1986). Integrated non-waste chloride processing of polymetallic oxidized raw materials. Leningrad, Russia (in Rus.).

[8] Melnik M.A. (1992). Physicochemical basis and complex chloride technology of processing zinc-oligoitic ores of Zhayremsky deposit. Alma-Ata, Kazakhstan.

[9] Shevko V.M., Daribaev Zh.B. (2004). Agglomeration-chlorinating firing of tailings of enrichment and overburden. IKTU, Kentau, Russia (in Rus.).

[10] Shevko V.M., Kapsaljamov B.A., Bishimbaev V.K., Kolesnikov A.S., Kartbaev S.K. (2009). Complex electrothermal processing of clinkers for the waelz - process of oxide Ajisai zinc-containing ores. SKSU named after M. Auezov, Shymkent, Kazakhstan. ISBN 9965-1-9173-5 (in Rus.).

[11] Shevko V.M., Ajtkulov D.K., Atamkulov B.B., Izbashanov K.S., Najmanbaev M.A. (2017). Complex electrothermal processing of poor oxide ore of the Achisay deposit. News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and engineering sciences. [Kompleksnaja jelektrotermicheskaja pererabotka bednoj oksidnoj rudy Achisajskogo mestorozhdenija // Izvestija nacional'noj akademii nauk Respubliki Kazahstan. Serij geologii i tehnicheskih nauk] 4: 177-183 (in Rus.).

[12] Bajbatsha A.B. (2008). Geology of Mineral Deposits - Tutorial. KNTU, Almaty, Kazakhstan (in Rus.).

[13] Dzhigiris D.D., Makhova M.F. (2002). Basis for the production of basalt fibers and articles: Monograph. Heat-and-powerengineer. Moscow, Russia (in Rus.).

[14] Aspanova L.G. (2000). Method for obtaining basalt fiber and a device for its implementation [Sposob poluchenija bazal'tovogo volokna i ustrojstvo dlja ego osushhestvlenija]. Patent of the Russian Federation 2149841 [Patent Rossijskoj Federacii 2149841] (in Rus.).

[15] Bagrjancev G.I., Koryhaev V.V., Kulagina N.V. and others (2009). Method of obtaining fiber from mineral raw materials [Sposob poluchenija volokna iz mineralnogo syrja]. Patent of the Russian Federation 2352531 [Patent Rossijskoj Federacii 2352531].

[16] Osnoc S.P., Ahmadeev V.F. (2010). Basalt continuous fiber [Bazaltovoe nepreryvnoe volokno]. Patent of the Russian Federation 2381188 [Patent RossijskojFederacii 2381188].

[17] Babievskaja I.Z., Gavricev K.S. and others (2007) Method for producing basalt fiber [Sposob poluchenija bazaltovogo volokna]. Patent of the Russian Federation 2297986 [Patent Rossijskoj Federacii2297986].

[18] Aknazarov S.H., Lukjashhenko V.G., Messerle V.E. (2013). Method for processing slime of chromate production [Sposob pererabotki shlama hromatistogo proizvodstva]. Innovation patent of the Republic of Kazakhstan 27146 [Innovacionnyj patent Respubliki Kazahstan 27146].

[19] Roine A. (2002). Outokumpu HSC Chemistry for Windows. Chemical reactions and equilibrium software with extensive thermochemical database. Outokumpu research, Pori.

[20] Scientific Group Thermodata Europe: [Electronic resource]. URL:http://sgte.net/en/ (Date of access: 03.01.2018).

[21] Kozlov K.B., Lavrov B.A. (2011). Calcium carbide production in an arc furnace and its analysis. SPbGTI, Saint-Petersburg, Russia (in Rus.).

[22] Ahnazarova S.A., Kafarov B.V. (1978). Methods for optimizing the experiment in the chemical industry. High school, Moscow, Russia.

[23] Ochkov V.F. (2007). Mathcad 14 for students, engineers and designers. BHV-Petersburg, St.-Petersburg, Russia (in Rus.).

Gasik M.I., Ljakishev N.P. (1999). Theory and technology of electrometallurgy of ferroalloys. JV Intermet Enginee-ring, Moscow, Russia (in Rus.).

Publication Ethics and Publication Malpractice
in the journals of the National Academy of Sciences of the Republic of Kazakhstan

For information on Ethics in publishing and Ethical guidelines for journal publication see http://www.elsevier.com/publishingethics and http://www.elsevier.com/journal-authors/ethics.

Submission of an article to the National Academy of Sciences of the Republic of Kazakhstan implies that the described work has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see http://www.elsevier.com/postingpolicy), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The National Academy of Sciences of the Republic of Kazakhstan follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (http://publicationethics.org/files/u2/New_Code.pdf). To verify originality, your article may be checked by the Cross Check originality detection service http://www.elsevier.com/editors/plagdetect.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will only accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the National Academy of Sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of Sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайте:

www:nauka-nanrk.kz

ISSN 2518-170X (Online), ISSN 2224-5278 (Print)

http://www.geolog-technical.kz/index.php/en/

Верстка *Д. Н. Калкабековой*

Подписано в печать 06.02.2019.
Формат 70х881/8. Бумага офсетная. Печать – ризограф.
16,7 п.л. Тираж 300. Заказ 1.

Национальная академия наук РК
050010, Алматы, ул. Шевченко 28, т. 272-13-19, 272-13-18