

Nuclear Reactions and X-Rays by Metals Combustion

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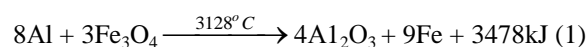
Abstract

Experimental verification of the hypothesis made by B.V. Bolotov on the foreign (new) elements formation as a result of low-energy nuclear reactions in combustion processes with Al-MeO (Fe₂O₃, PbO, CuO etc.) thermites was executed. The combustion process of thermites was accompanied by X-rays with the energy of several keV that confirm the probability of nuclear reactions during combustion. The combustion products of Al-Fe₂O₃ thermite with the extra pure initial reagents (99.7 mass %) burned on air were examined by XRF and ICP-MS methods. Condensed combustion products of Al-Fe₂O₃ thermites burned on air contained abnormally high concentrations of Ca (up to 0.55 mass %) determined by EDX and ICP-MS.

1. Introduction

Experimental data on the non-radioactive elements transmutation at low temperatures (T < 3000°C) including the release of "excess energy" of unknown nature by electrical explosion of metal conductors (EEMC) such as wires, foils, and cylinders were reported in [1,2]. Si and Al in an amount of up to 8.0 (!) mass % were found in the explosion products of EEMC of Ti in water [2]. EEMC of Fe-Al alloys in Ar results in W (5.9 mass %), Cu (up to 4.0 mass %) and Mn (0.4 mass %) formation [3]. The appearance of the significant amount (up to several mass %) of foreign elements by EEMC has traditionally been viewed as a result of corrosion of explosion chamber [4] or impurities presence in the initial reagents [5]. Nanosecond impulses of X-ray with the energy of up to 100 keV [6,7] and neutrons [8] was fixed by EEMC under the electric energy input into the wire of up to 10¹³ W/cm². The theoretical mechanism of low-energy nuclear reactions is not justified [9-12] due to the lack of adequate models of atom [12] different from the rather contradictory "standard model" based on Large Hadron Collider (LHC) studies (Fig. 1) [13]. The theoretical and experimental evidence for the low-energy nuclear reactions in an organic (bacterial, human body, etc.) [14] as well as in an inorganic systems (plasma, electrolysis, combustion and explosion, etc.) was proved in the works of C. L. Kervran [11] and B.V. Bolotov [12].

Self-propagated High-temperature Synthesis (SHS) in the Ti-B system is accompanied by the release of X-rays with the energy of about 5 keV [15]. The presence of X-rays, radio frequency and other radiation by SHS [16] can be an indicator of the nuclear reactions during SHS combustion (reaction 1 for example). In the case of SHS or thermite reactions the elements are exist as low-temperature ionized plasma (eq. 1, at adiabatic temperature).



The mechanism of the Coulomb barrier of nuclear fusion weakening in presence of powerful streams of electrons (up to 10⁶ A/mm²) was suggested in [12] and discussed in [17].



Fig. 1. Standard model of atomic nuclei elementary particles (version 2000s) [13].

In this work we carried out an experimental testing of the elemental composition of the combustion products of thermites (Al + Fe₂O₃) burned in air with the super pure reagents usage. The presence or absence of the foreign (new) elements in the condensed combustion products could be an argument to support or refuse the low-energy nuclear reactions during thermites combustion. We investigated the thermites (Al + Fe₂O₃) combustion due to their availability among the other highly ionized and highly exothermic burning systems, where nuclear reactions are more probable compared to the equilibrium ones [18]. The usage of high-purity reagents (99.9 mass %) is allowing validation the presence or absence of the foreign (new) products of low-energy transmutation of elements in measureable amounts by combustion.

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2. Experiment

2.1. Combustion Process

The combustion of powdery non-pressed thermite samples (Al + Fe₂O₃) was executed on air. We used the high-purity oxidizer Fe₂O₃ (99.9 mass % purity, particle size > 50 µm). Aluminum powder ASD-4 (99.7 mass %, particle size ~10 µm) whose properties are well studied [19] was used as a reducer in thermite formulations. The powdery thermite mixes were freely poured on tungsten plates of high purity (99.9 mass %). The Al and Fe₂O₃ powders were mixed with the mass ratios Al / Fe₂O₃ = 1.5, 1.0 and 0.7 (3 parallel experiments for each ratio).

Impurities in the reactants were presented in trace amounts (Table) that was also confirmed in [20].

Thermite samples were ignited by the gas Bunsen burner. The maximal burning temperature for the Al / Fe₂O₃ = 1.5 samples was 2790 ± 50 °C according to the thermocouple measurements (WRe5/WRe20 thermocouples with the diameter of 100 µm). The temperature profiles and burning rate for the thermite (Al + Fe₂O₃) combustion are widely studied [21] and, thus, they are not given in this paper.

Table 1. Composition of reactants and combustion products of thermite (Al + Fe₂O₃) burned on air

Reactants (1-3) and combustion products (4-6)	Metal content*, (mass % ± 0.01 mass %)										
	W	Fe	Al	Ca	Cr	K	Mg	Na	Si	Mn	Ni
1. W plates	99.95	<0.01	0.02	<0.01	0.02	0.01	0.01	<0.01	<0.01	<0.01	<0.01
2. Fe ₂ O ₃ **	<0.01	70.04	<0.01	<0.01	0.02	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
3. Al ASD-4**	<0.01	0.12	99.71	<0.01	0.03	0.02	0.01	<0.01	0.15	0.01	0.03
4. Al/Fe ₂ O ₃ = 1.5**	<0.01	33.74	56.47	0.38	0.01	0.13	0.04	0.16	0.04	0.06	0.02
5. Al/Fe ₂ O ₃ = 1.0**	<0.01	49.05	46.04	0.55	0.02	0.10	0.06	0.24	0.01	0.10	0.03
6. Al/Fe ₂ O ₃ = 0.7**	<0.01	62.78	26.13	0.32	0.01	0.06	0.03	0.02	0.01	0.10	0.03

* Metal content in acids used for analysis (HF, HNO₃, HCl) and in bi-distilled water was not more than 0.005 mass %.

**The residue was H, F, N, O, S, and P.

2.2. Combustion Products Analyses

The composition of thermite combustion products is normally not under thorough analysis in the literature due to the low-purity reagents usage (<95 mass % purity). Another problem in combustion products analysis is low sensitive techniques usage (XRD or EDS) with an error of elemental or phase composition determination ± 1-2 mass %.

In this work the solid combustion products were collected after combustion and they were dissolved in a mixture of HF, HNO₃, HCl. Then the solutions were analysed with atomic emission spectrometry with inductively coupled plasma (spectrometer ICAP 6300 DUO) and with XRF analysis (spectrometer D2 PHASER). These methods allow determining the concentration of elements in samples with an accuracy of ± 0.01 mass %. Dissolution of combustion products for the ICP-MS analysis was performed in ICAP spectrometer in polypropylene tubes at T=100°C. Composition of the reactants and combustion products are shown in Table 1.

3. Discussion

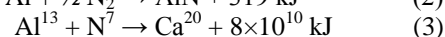
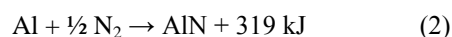
Elemental Ca was presented in trace amount in reactants (Table 1). On the contrary, elemental Ca content was ≤0.55 mass % in the combustion products of the thermites (Fig. 2). Accuracy of elemental analysis (ICP-MS + XRF) was confirmed by the correlation of the content of elemental Al and Fe in the combustion products (Fig. 2,a).

What could be the reason of such a high elemental Ca concentration in thermites combustion products (0.32-0.55 mass %)? It is rather difficult to explain Ca appearance with the only chemical processes took place by combustion: the elemental composition of reactants should be the same for the reaction products. However, theoretically, the emergence of new elements (Ca, Mg, Si, Na, K) appeared due to low-energy nuclear reactions by combustion for thermites was predicted in [12].

It should be noted that light elements (H, F, N, O, S, and P) were excluded from the analysis (Table 1) because they may be the components of oxides, nitrides and acids presented in probes. Thus, only metals were analysed.

The usage of the other analytical methods such as XRD or EDX (sensitivity ± 1-2 mass %) does not allow to judge the purity of analysed samples. Therefore, the usage of these methods when working with high-purity reagents is useless. Micro-analytical chemical methods do not eliminate errors by analyses also.

Thus, during thermites (Al + Fe₂O₃) combustion on air not only chemical interaction of aluminum and nitrogen occurs (eq. 2) probably [22,23], but nuclear transmutation according to reaction (eq. 3) also. Nuclear reactions could be the reason of the presence of X-rays accompanying SHS processes [15].



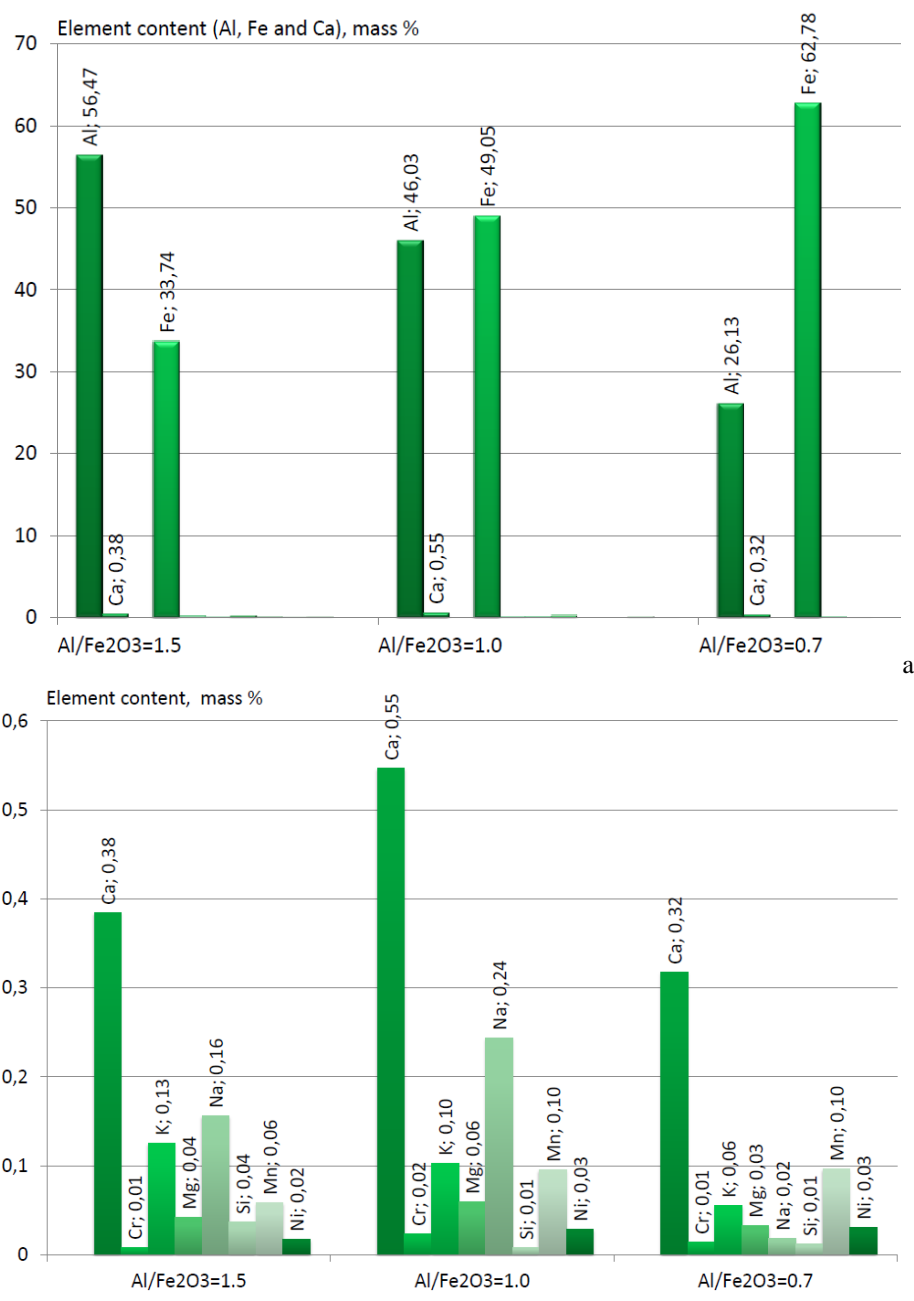


Fig. 2. Element content in combustion products of thermite (Al + Fe₂O₃) burned on air: a) Al, Fe and Ca content; b) Ca, Cr, K, Mg, Na, Si, and Mn content.

Table 2. Calculated composition of combustion products of thermite (Al + Fe₂O₃) at 0.1 and 1.0 MPa.

Combustion product	Content at pressure, mass %	
	0.1 MPa	1.0 MPa
O (gas)	2×10^{-3}	0
Al (gas)	0.03	0.01
Fe (gas)	6.31	0.06
O ₂ (gas)	1×10^{-4}	0
AlO (gas)	0.01	10×10^{-4}
Al ₂ O (gas)	0.07	0.09
Al ₂ O ₂ (gas)	9×10^{-4}	2×10^{-4}
FeO (gas)	0.03	7×10^{-4}
Al ₂ O ₃ (condensed)	47.63	47.65
Fe (condensed)	45.91	52.19

4. Conclusion

A formation of Ca by the Kervran-Bolotov reaction (3) along with the detailed studied formation of AlN (2) on air during thermite (Al + Fe₂O₃) combustion was found. Ca formation was unpredictable by theoretical calculation of the combustion products composition (Table 2) in frame of traditional purely chemical approach. *The content of Ca increased in ~5500 % in the combustion products as compared to its content in the reactants. This experimental fact cannot be explained by chemical reactions only.*

This result requires experimental verification for other thermite combustion with super-pure reagents application. The nature of the low-temperature

nuclear reaction is probably the same for the living and the highly ionized systems (plasma, combustion, laser irradiation). This was indicated by the same order of the energy (from a few keV/atom to several tens of MeV/atom) [12]. The chemical and low temperature nuclear reactions can be consecutive stages of the same combustion process thus. Chemical highly exothermal processes in highly ionized systems may result in further nuclear interactions. When sufficient energy required overcoming the Coulomb barrier is introduced to the reactive system during combustion or explosion, the process of interaction, for example, between N_2 and Al cannot dwell on aluminum nitride, and continue to form Ca (eq. 3).

This result can be considered as a confirmation of the hypothesis that there are low-temperature nuclear reactions by combustion. Experimental confirmation of the Kervran-Bolotov reactions (eq. 3) in combustion requires further study and opens up broad prospects for understanding the mechanisms of such phenomena accompanied superadiabatic combustion, explosion hazard of gaseous oxygen with traces of oil, increase the efficiency of diesel combustion with water additives, plasma electrolysis, atmospheric, astrophysical processes and many others [24,25].

4. Acknowledgement

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