

A. B. Baeshov¹, G. K. Aibolova², E. Zh. Tuleshova², M. A. Ozler³

¹Institute of Fuel, Catalysis and Electrochemistry named after D. V. Sokolsky, Almaty, Kazakhstan,

²Kh. A. Yessevi Kazakh-Turkish University, Turkestan, Kazakhstan,

³Mugla Sitki Kocman University, Mugla, Turkey.

E-mail: gulnar.aibolova@ayu.edu.kz, elmira.tuleshova@ayu.edu.kz

ELECTROCHEMICAL OXIDATION OF NITROGEN (II) OXIDE IN THE NEUTRAL MEDIUM

Abstract. Electrochemical oxidation of nitrogen oxide was considered in the work. The study was carried out in the sodium sulphate solution. The effects of current density in the anode, electrolyte concentration, granular electrode layer thickness and volume of dispersed gas on the oxidation rate of nitrogen (II) oxide and the current output of its oxidation were investigated. The experiments were carried out in a thermostated electrolysis cell in galvanostatic conditions. A granular graphite electrode was used as anode and graphite plate as a cathode, the duration of the experiments was 0.5 hours. Nitrogen (II) oxide gas was supplied at a certain speed at the bottom of the electrolysis cell. The study discovered that nitrate ions were formed as the main product. Optimal parameters of the electrochemical oxidation of nitrogen oxide were determined.

Keywords: electrochemistry, electrolysis, nitrogen oxide, granular electrode, current density.

One of the main sources of formation of pollutant emissions into the environment is the chemical and metallurgical industries. Therefore, it is crucial today to process production waste and remove valuable components from them. Due to the development of technology, especially non-ferrous metallurgy and motor transport, a large amount of toxic gases are emitted into the atmosphere. These substances have a great impact on the lives of human beings, plants and animals [1-3]. According to the latest data, 12 million tons of nitrogen oxides (calculated for nitrogen) penetrate air per year [4].

It should be noted that the total nitrogen oxides are emitted from various pollutants – 40% from vehicles and other transport engines, 30% from thermal power plants, 20% from fossil fuels and 10% from other sources [4]. Despite the technological difficulties in processing production wastes containing nitrogen (II) oxide, which is formed as a result of various processes, it is important to deactivate them and obtain the desired products.

One of the most effective and simplest methods of waste deactivation is currently an electrochemical method. Subsequently, granular electrodes are used to intensify electrochemical methods. The peculiarity of these electrodes is that the process takes place in the amount of granular electrodes of the electrolysis cell. We conducted a number of studies to deactivate production waste containing nitrogen (II) oxide in an electrochemical way based on the oxidation [5-9].

In this regard, in our work, we considered the possibility of oxidizing nitrogen oxide gas by electrolysis using graphite electrodes in the anode space in sodium sulphate solution.

The study was carried out in a thermostated electrolysis cell of 100 ml in galvanostatic conditions. The granular graphite electrodes (length - 3 ml, diameter - 1.5 ml) were used as anode and graphite plate as a cathode, the duration of the experiments was 0.5 hours. Nitrogen (II) oxide gas was supplied at a certain speed at the bottom of the electrolysis cell. The effects of current density in the anode, electrolyte concentration, granular electrode layer thickness and volume of dispersed gas on the oxidation rate of nitrogen (II) oxide and the current output of its oxidation were investigated. After the electrolysis, nitrate ions formed in the solution were analyzed [10].

The effect of the current density on the oxidation process of nitrogen (II) oxide was considered in the range of 25-400 A/m². As the current density increases, the oxidation rate of nitrogen (II) oxide and the current output of its oxidation decrease (figure 1). Apparently, as the current density increases, alongside with the nitrogen oxide oxidation process in the anode, the proportion of oxygen increases and leaves the reaction zone without interacting with the NO gas.

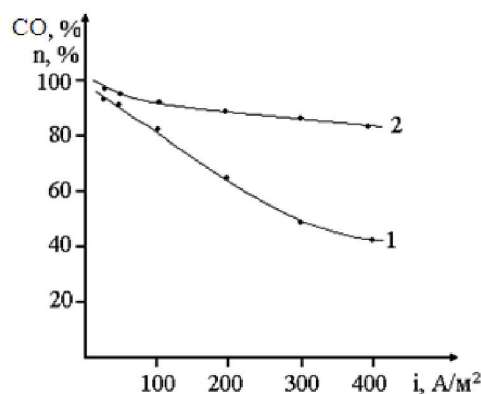


Figure 1 – The effect of current density on the current output of nitrogen (II) oxide oxidation (1) and on the oxidation rate (2):
C_{Na₂SO₄} = 1M, τ = 0.5 h, δ = 2 cm, V (NO) = 300 ml

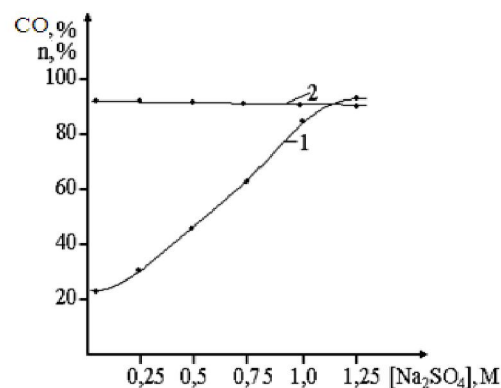


Figure 2 – The effect of the sodium sulphate solution concentration on the current output of nitrogen (II) oxide oxidation (1) and the oxidation rate (2):
i = 100 A/m², τ = 0.5 h, δ = 2 cm, V(NO) = 300 ml

When we increase the sodium sulphate concentration in the range of 0.1-1.25 mol/l, it is observed that the oxidation rate of nitrogen (II) oxide is slightly reduced (figure 2, curve 2) and the current output increases significantly (figure 2, curve 1). In our view, gas bubbles of nitrogen (II) oxide can be oxidized by interaction with oxygen in the form of atomic and molecules that are formed when they collide with anode or are separated on the electrode surface. As the concentration of the sodium sulphate increases, it is assumed that the small gas bubbles of oxygen gas are formed and the possibility of their participation in the reaction increases.

We believe that the granules we use are charged particles in all volumes, so the height of these electrodes can have a major impact on the oxidation process. Therefore, the effect of the granular electrode layer thickness on the oxidation rate of the nitrogen (II) oxide and the current output of the oxidation in the sodium sulphate solution was studied in the range of 0.5-5 cm, the following result was achieved.

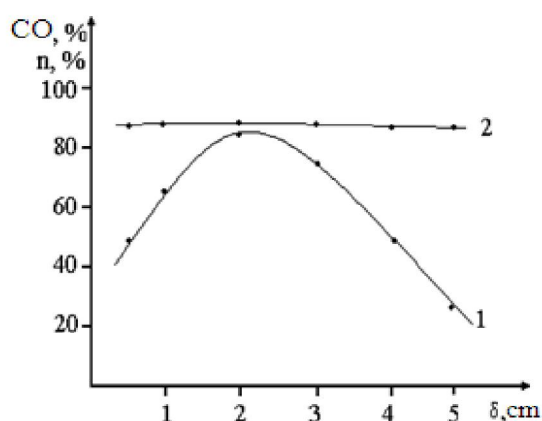


Figure 3 – The effect of the granular electrode layer thickness on the current output of the nitrogen (II) oxide oxidation (1) and the oxidation rate (2): i = 100 A/m²,
C_{Na₂SO₄} = 1M, τ = 0.5 h, V (NO) = 300 ml

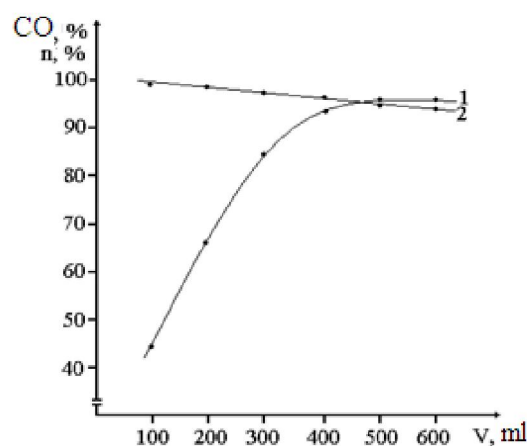


Figure 4 – The effect of gas volume on the current output of nitrogen (II) oxide oxidation (1) and the oxidation rate (2):
i = 100 A/m², [Na₂SO₄] = 1M, τ = 0.5 h, δ = 2 cm

As the granular electrode layer thickens to a thickness of 2 cm, the oxidation rate of nitrogen (II) oxide is slightly reduced, while the current output increases to 85% (figure 3). The thicker the layer, the less the current output is observed. In our view, as the thickness of the granular electrode layer increases, the contact of the particles weakens and affects the electrode polarization value and the non-inactive zone and bipolar granules emerge in the electrode volume.

Our studies also examined the effects of oxidation reaction and the volume of gas passing through the electrolysis. As can be seen from figure 4, an excessive increase of the gas volume can lead to a reduction in the oxidation rate. In our opinion, the rapidly passing gas, due to the inability to fully oxidize within half an hour, lowers the oxidation rate of the nitrogen oxide. And as the volume of gas is increased, an increase in the current output of the gas oxidation is observed. Because, according to the law of mass action, the higher the volume of the reaction substances, the easier a chemical reaction proceeds. In our case, this is the case.

In conclusion, the anode oxidation of nitrogen (II) oxide gas was investigated using granular electrodes. The peculiarity of these electrodes is that the process takes place in granular electrodes with a developed surface area. During the oxidation, the formation of the nitrates ions was determined. The results of the study can be used for the development of technology for waste decontamination with nitrogen (II) oxide.

А. Б. Башов¹, Г. Т. Айболова², Э. Ж. Тулешова², М. А. Өзлер³

¹«Д. В. Сокольский атындағы жанармай, катализ және электрохимия институты» АҚ, Алматы, Қазақстан,

²Қожа Ахмет Ясауи атындағы Халықаралық қазақ-түрік университеті, Түркістан, Қазақстан,

³Мугла Сыткы Кочман университеті, Мугла, Түркия

АЗОТ (II) ОКСИДІН ЭЛЕКТРОХИМИЯЛЫҚ ЖОЛМЕН НЕЙТРАЛ ОРТАДА ТОТЫҚТЫРУ

Аннотация. Жұмыста азот оксидін электрохимиялық жолмен тотықтыру мүмкіндігі қарастырылды. Зерттеу жұмыстары натрий сульфаты ерітіндісінде жүргізілді. Азот (II) оксидінің тотығу дәрежесі мен тотығуының ток бойынша шығымына – анодтағы ток тығыздығының, электролит концентрациясының, түйіршікті электродтар қабаты қалыңдығының және жіберілген газ көлемінің әсерлері қарастырылды. Тәжірибелер гальваностатикалық жағдайда термостатталған электролизерде жүргізілді. Анод ретінде – түйіршікті графит электродтары, ал катод ретінде – графит пластинкасы қолданылды, тәжірибелердің ұзақтығы 0,5 сағ. Азот (II) оксиді газы электролизердің төменгі жағынан белгілі бір жылдамдықпен беріліп отырылды. Зерттеу барысында негізгі өнім ретінде нитрат иондары түзілетіні анықталды. Азот оксидінің электрохимиялық жолмен тотықтыруының оңтайлы параметрлері анықталды.

Түйін сөздер: электрохимия, электролиз, азот оксиді, түйіршікті электрод, ток тығыздығы.

А. Б. Башов¹, Г. Т. Айболова², Э. Ж. Тулешова², М. А. Өзлер³

¹АО «Институт Топлива, катализа и электрохимии им. Д. В. Сокольского», Алматы, Казахстан,

²Международный казахско-турецкий университет им. Ходжи Ахмеда Ясави, Туркестан, Казахстан,

³Университет Муглы им. Сыткы Кочман, Мугла, Турция

ЭЛЕКТРОХИМИЧЕСКОЕ ОКИСЛЕНИЕ ОКСИДА АЗОТА (II) В НЕЙТРАЛЬНОЙ СРЕДЕ

Аннотация. В работе изучен процесс электрохимического окисления оксида азота. Исследования проводились в растворе сульфата натрия. На выход по току и степень окисления оксида азота (II) изучено влияние плотности тока на аноде, концентрация электролита, толщина слоя кускового электрода и объем газа. Опыты проводились в гальваностатических условиях в термостатированном электролизере. В качестве анода использовали кусковой графитовый электрод, а в качестве катода графитовую пластинку, продолжительность электролиза 0,5 час. Газ оксид азота (II) подавали с нижней части с одинаковой скоростью. Установлено, что основным продуктом окисления являются нитрат-ионы. Определены оптимальные параметры электрохимического окисления оксида азота.

Ключевые слова: электрохимия, электролиз, оксид азота, кусковой электрод, плотность тока.

Information about authors:

Baeshov Abduali Baeshovich, doctor of chemical sciences, academic of the National Academy of Sciences of Kazakhstan, head of the laboratory D. V. Sokolsky Institute of Fuel, Catalysis and Electrochemical, Almaty, Kazakhstan; bayeshov@mail.ru; <https://orcid.org/0000-0003-0745-039X>

Aibolova Gulnar Kurbantayevna, candidate of technical sciences, Head of the Department of Laboratory Studies Kh. A. Yassawi Kazakh-Turkish University, Turkestan, Kazakhstan; gulnar.aibolova@ayu.edu.kz; <https://orcid.org/0000-0003-0322-9217>

Tuleshova Elmira Zhanbirbayevna, Candidate of Chemistry, Associate Professor, Deputy Dean of the Medical Faculty Kh. A. Yassawi Kazakh-Turkish University, Turkestan, Kazakhstan; elmira.tuleshova@ayu.edu.kz; <https://orcid.org/0000-0003-2249-9570>

Ozler Mehmet Ali, doctor, professor Mugla Sitki Kocman University, Mugla, Turkey; aozler@mu.edu.tr

REFERENCES

- [1] Bayeshov A.B. Ecology and clean water problems [Ékologiya jáne taza su problemaları]. Almaty: Welders, **2003**. 210 p. (in Kaz.).
- [2] Akbasova A.Zh., Sainova G.A. Ecology: a textbook for higher education [Ékologiya: joǵarı oqıw omına arnalǵan oqıw quralı]. Almaty: Bastau publishing house, **2003**. 292 p. (in Kaz.).
- [3] Sadanova A.K., Abzhalelov A.B., Taubekova G.K., Askarova U.B. Ecology [Ékologiya]. Almaty, **2001**. 172 p. (in Kaz.).
- [4] Bayeshov A.B., Aitbaev N. Almaty, chemistry at school [Ximiya mektepte]. **2015**. N 3. P. 94-97 (in Kaz.).
- [5] Aibolova G.K., Bayeshov A.B. Industry of Kazakhstan [Promıshlennost Kazaxstana]. Almaty, **2005**. N 5. P. 93-94 (in Kaz.).
- [6] Bayeshov A.B., Aibolova G.K., Bayeshova A.K. Oxidation of oxide nitrogen (II) [Sposob okisleniya oksida azot (II)]. Preliminary Patent of the Republic of Kazakhstan N 18716 [Predvaritelnyi patent Respubliki Kazakhstan] (in Rus.).
- [7] Aibolova G.K., Bayeshov A.B. Reports of the National Academy of Sciences of the Republic of Kazakhstan [QR UǵA Bayandamaları]. Almaty, **2005**. N 6. P. 27-31 (in Kaz.).
- [8] Aibolova G.K., Tuleshova E.Zh. // Russian Journal of Physical Chemistry A. **2018**. Vol. 92, N 11. P. 2348-2350. DOI 10.1134/S003602441811002X (in Eng.).
- [9] Bayeshov A.B., Aibolova G.K., Bayeshova A.K. Reports of the National Academy of Sciences of the Republic of Kazakhstan [QR UǵA Bayandamaları]. Almaty, **2007**. N 2(362). P. 10-13 (in Kaz.).
- [10] Uniform Methods for Analyze Water [Wnıfıcirovannıe metodı analiza vod]. Sub. dr. Prof. Yu. Loury. M.: Chemistry, **1973**. 376 p. (in Rus.).
- [11] Druzhnik L.I. Efficient use of natural gas in industrial environments: a Handbook [Effektivnoye ispol'zovaniye prirodnogo gaza v promyshlennykh usloviyakh: Spravochnik]. M.: Energoatomizdat, **1992** (in Rus.).
- [12] Balabekov O.S., Baltabaev L.Sh. Gas cleaning in the chemical industry. Processes and devices [Ochistka gazov v khimicheskoy promyshlennosti. Protsestry i apparaty]. M.: Chemistry, **1991**. 256 p. (in Rus.).
- [13] Hill S.C., Smoot L.D. Modeling of nitrogen oxides formation and destruction in combustion sustems // Prog. Energ. Comb. Sci. **2000**. Vol. 26. P. 417 (in Eng.).
- [14] Lange M. Vorschriften und technische Habnahmen zur Schwefelfioxid-und Stickstoffoxid-Emission-sminderung // Technische Mitteilungen. **1985**. Vol. 78, N 1/2. P. 3-8 (in Eng.).
- [15] Tororoshnikov N. Environmental protection technique [Tekhnika zashchity okruzhayushchey sredy]. M.: Chemistry, **1981**. P. 211 (in Rus.).
- [16] Belov P.S., Golubaev I.A., Nizova S.A. Ecology of production of chemical products from petroleum hydrocarbons and gas [Ekologiya proizvodstva khimicheskikh produktov iz uglevodorodov nefti i gaza]. M.: Chemistry, **1991**. 56 p. (in Rus.).
- [17] Wetstone S. Acid Rain: The International Perspective // Environmental Policy and Law. October 1983. Vol. 11, N 1/2. P. 31-33 (in Eng.).
- [18] The trouble N.V., Nedospasov A.A. Bioorganic chemistry [Bioorganicheskaya khimiya]. **2006**. Vol. 32, N 1. P. 3-26 (in Rus.).
- [19] Gladchenko I.A., Kashevsky A.V., Khudyakova R.V., Safronov A.Yu. Electrochemistry [Elektrokhimiya]. **2005**. Vol. 41, N 11. P. 1386-1390 (in Rus.).
- [20] Proskuryakov S.Ya., Konoplyannikov A.G., Skvortsov V.G., Mandurgin A.A., Fedoseev V.M. Advances in chemistry [Uspekhi khimii]. **2005**. Vol. 74, N 9. P. 939-952 (in Rus.).