

**ACADEMIC SCIENTIFIC
JOURNAL OF CHEMISTRY**

ISSN: 2224-5286 (Print)
ISSN: 2518-1491 (Online)

**№4
2025**

ISSN 2518-1491 (Online),
ISSN 2224-5286 (Print)



ACADEMIC SCIENTIFIC JOURNAL OF CHEMISTRY

4 (465)

October – December 2025

PUBLISHED SINCE JANUARY

1947 PUBLISHED 4 TIMES A YEAR

ALMATY, NAS RK

Editor in chief:

ZHURINOV Murat Zhurinovich, doctor of chemistry, professor, academician of NAS RK, President of NAS RK RPA, general director of JSC "D.V. Sokolsky Institute of fuel, catalysis and electrochemistry (Almaty, Kazakhstan) <https://www.scopus.com/authid/detail.uri?authorId=6602177960>, <https://www.webofscience.com/wos/author/record/2017489>

Editorial board:

ADEKENOV Sergazy Mynzhasarovich (deputy editor-in-chief) doctor of chemical sciences, professor, academician of NAS RK, director of the International Scientific and Production Holding «Phytochemistry» (Karaganda, Kazakhstan) <https://www.scopus.com/authid/detail.uri?authorId=7006153118>, <https://www.webofscience.com/wos/author/record/48648658>

AGABEKOV Vladimir Enokovich (deputy editor-in-chief), doctor of chemistry, professor, academician of NAS of Belarus, honorary director of the Institute of Chemistry of new materials (Minsk, Belarus) <https://www.scopus.com/authid/detail.uri?authorId=7004624845>, <https://www.webofscience.com/wos/author/record/28920574>

STRNAD Miroslav, head of the laboratory of the Institute of Experimental Botany of the Czech Academy of Sciences, professor (Olomouc, Czech Republic) <https://www.scopus.com/authid/detail.uri?authorId=36789185000>, <https://www.webofscience.com/wos/author/record/18379>

BURKITBAYEV Mukhambetkali, doctor of chemistry, professor, academician of NAS RK, (Almaty, Kazakhstan) <https://www.scopus.com/authid/detail.uri?authorId=8513885600>, <https://www.webofscience.com/wos/author/record/691218>

HOHMANN Judith, head of the department of pharmacognosy, faculty of Pharmacy, University of Szeged, director of the interdisciplinary center for Life sciences (Szeged, Hungary) <https://www.scopus.com/authid/detail.uri?authorId=7004457196>, <https://www.webofscience.com/wos/author/record/15630788>

ROSS Samir, Ph.D, professor, school of Pharmacy, National Center for scientific research of Herbal Products, University of Mississippi (Oxford, USA) <https://www.scopus.com/authid/detail.uri?authorId=7401610128>, <https://www.webofscience.com/wos/author/record/47926269>

KHUTORYANSKY Vitaly, Ph.D, pharmacist, professor at the University of Reading (Reading, England) <https://www.scopus.com/authid/detail.uri?authorId=35606915700>, <https://www.webofscience.com/wos/author/record/221621>

TELTAYEV Bagdat Burkhanbayuly, doctor of technical sciences, professor, academician of NAS RK, Ministry of Industry and infrastructure development of the Republic of Kazakhstan (Almaty, Kazakhstan) <https://www.scopus.com/authid/detail.uri?authorId=6506225641>, <https://www.webofscience.com/wos/author/record/72161>

PHARUK Asana Dar, professor at Hamdard al-Majid college of Oriental medicine, faculty of Oriental medicine, Hamdard University (Karachi, Pakistan) <https://www.scopus.com/authid/detail.uri?authorId=55884056900>, <https://www.webofscience.com/wos/author/record/1796996>

FAZYLOV Serik Drakhmetovich, doctor of chemistry, professor, academician of NAS RK, deputy director of the Institute of Organic Synthesis and Coal Chemistry (Karaganda, Kazakhstan) <https://www.scopus.com/authid/detail.uri?authorId=6701472056>, <https://www.webofscience.com/wos/author/record/1541357>

ZHOROBEKOVA Sharipa Zhorobekovna, doctor of chemistry, professor, academician of NAS of Kyrgyzstan, Institute of Chemistry and chemical technology of NAS KR (Bishkek, Kyrgyzstan) <https://www.scopus.com/authid/detail.uri?authorId=6602652060>, <https://www.webofscience.com/wos/author/record/31723468>

KHALIKOV Jurabay Khalikovich, doctor of chemistry, professor, academician of the Academy of Sciences of Tajikistan, V.I. Nikitin Institute of Chemistry AS RT (Tajikistan) <https://www.scopus.com/authid/detail.uri?authorId=6603735641>, <https://www.webofscience.com/wos/author/record/9567106>

FARZALIEV Vagif Medzhid ogly, doctor of chemistry, professor, academician of NAS of Azerbaijan (Azerbaijan) <https://www.scopus.com/authid/detail.uri?authorId=6601962486>, <https://www.webofscience.com/wos/author/record/21617033>

GARELIK Hemda, PhD in chemistry, president of the department of Chemistry and Environment of the International Union of Pure and Applied Chemistry (London, England) <https://www.scopus.com/authid/detail.uri?authorId=56010090400>, <https://www.webofscience.com/wos/author/record/29866743>

ACADEMIC SCIENTIFIC JOURNAL OF CHEMISTRY

ISSN 2518-1491 (Online),

ISSN 2224-5286 (Print)

Owner: «Central Asian Academic Research Center» LLP (Almaty).

The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan № **KZ23VPY00121156**, issued 05.06.2025

Thematic scope: *organic chemistry, inorganic chemistry, catalysis, electrochemistry and corrosion, pharmaceutical chemistry and technology.*

Periodicity: 4 times a year.

<http://chemistry-technology.kz/index.php/en/arhiv>

© «Central Asian Academic Research Center» LLP, 2025

Editorial address: JSC «D.V. Sokolsky institute of fuel, catalysis and electrochemistry», 142, Kunayev str., of. 310, Almaty, 050100, tel. 291-62-80, fax 291-57-22, e-mail: orgcat@nursat.kz

Бас редактор:

ЖҰРЫНОВ Мұрат Жұрыңұлы, химия ғылымдарының докторы, профессор, ҚР ҰҒА академигі, РБҚ ҚР ҰҒА президенті, АҚ «Д.В. Сокольский атындағы Отын, катализ және электрохимия институтының» бас директоры (Алматы, Қазақстан) <https://www.scopus.com/authid/detail.uri?authorId=6602177960>, <https://www.webofscience.com/wos/author/record/2017489>

Редакция алқасы:

ӘДЕКЕНОВ Серғазы Мыңжасарұлы (бас редактордың орынбасары), химия ғылымдарының докторы, профессор, ҚР ҰҒА академигі, «Фитохимия» Халықаралық ғылыми-өндірістік холдингінің директоры (Қарағанды, Қазақстан) <https://www.scopus.com/authid/detail.uri?authorId=7006153118>, <https://www.webofscience.com/wos/author/record/48648658>

АГАБЕКОВ Владимир Енокович (бас редактордың орынбасары), химия ғылымдарының докторы, профессор, Беларусь ҰҒА академигі, Жаңа материалдар химиясы институтының құрметті директоры (Минск, Беларусь) <https://www.scopus.com/authid/detail.uri?authorId=7004624845>, <https://www.webofscience.com/wos/author/record/28920574>

СТРНАД Мирослав, профессор, Чехия ғылым академиясының Эксперименттік ботаника институтының зертхана меңгерушісі (Оломоуц, Чехия) <https://www.scopus.com/authid/detail.uri?authorId=36789185000>, <https://www.webofscience.com/wos/author/record/18379>

БҮРКІТБАЕВ Мұхамбетқали, химия ғылымдарының докторы, профессор, ҚР ҰҒА академигі, (Алматы, Қазақстан) <https://www.scopus.com/authid/detail.uri?authorId=8513885600>, <https://www.webofscience.com/wos/author/record/691218>

ХОХМАНН Джулит, Сегед университетінің Фармацевтика факультетінің Фармакогнозия кафедрасының меңгерушісі, Жаратылыстану ғылымдарының пәнаралық орталығының директоры (Сегед, Венгрия) <https://www.scopus.com/authid/detail.uri?authorId=7004457196>, <https://www.webofscience.com/wos/author/record/15630788>

РОСС Самир, PhD, Миссисипи университетінің Өсімдік өнімдерін ғылыми зерттеу ұлттық орталығы, Фармация мектебінің профессоры (Оксфорд, АҚШ) <https://www.scopus.com/authid/detail.uri?authorId=7401610128>, <https://www.webofscience.com/wos/author/record/47926269>

ХУТОРЯНСКИЙ Виталий, философия докторы (PhD, фармацевт), Реддинг университетінің профессоры (Реддинг, Англия) <https://www.scopus.com/authid/detail.uri?authorId=35606915700>, <https://www.webofscience.com/wos/author/record/221621>

ТЕЛТАЕВ Бағдат Бұрханбайұлы, техника ғылымдарының докторы, профессор, ҚР ҰҒА академигі, Қазақстан Республикасы Индустрия және инфрақұрылымдық даму министрлігі (Алматы, Қазақстан) <https://www.scopus.com/authid/detail.uri?authorId=6506225641>, <https://www.webofscience.com/wos/author/record/72161>

ФАРУК Асана Дар, Хамдар аль-Маджида Шығыс медицина колледжінің профессоры, Хамдард университетінің Шығыс медицина факультеті (Карачи, Пәкістан) <https://www.scopus.com/authid/detail.uri?authorId=55884056900>, <https://www.webofscience.com/wos/author/record/1796996>

ФАЗЫЛОВ Серік Драхметұлы, химия ғылымдарының докторы, профессор, ҚР ҰҒА академигі, Органикалық синтез және көмір химиясы институты директорының ғылыми жұмыстар жөніндегі орынбасары (Қарағанды, Қазақстан) <https://www.scopus.com/authid/detail.uri?authorId=6701472056>, <https://www.webofscience.com/wos/author/record/1541357>

ЖОРОБЕКОВА Шарипа Жоробекқызы, химия ғылымдарының докторы, профессор, Кыргызстан ҰҒА академигі, ҚР ҰҒА Химия және химиялық технология институты (Бішкек, Кыргызстан) <https://www.scopus.com/authid/detail.uri?authorId=6602652060>, <https://www.webofscience.com/wos/author/record/31723468>

ХАЛИКОВ Джурабай Халикович, химия ғылымдарының докторы, профессор, Тәжікстан ҒА академигі, В.И. Никитин атындағы Химия институты (Душанбе, Тәжікстан) <https://www.scopus.com/authid/detail.uri?authorId=6603735641>, <https://www.webofscience.com/wos/author/record/9567106>

ФАРЗАЛИЕВ Вагиф Меджидоглы, химия ғылымдарының докторы, профессор, АҰҒА академигі (Баку, Әзірбайжан) <https://www.scopus.com/authid/detail.uri?authorId=6601962486>, <https://www.webofscience.com/wos/author/record/21617033>

ГАРЕЛИК Хемда, философия докторы (PhD, химия), Халықаралық таза және қолданбалы химия одағының Химия және қоршаған орта бөлімінің президенті (Лондон, Англия) <https://www.scopus.com/authid/detail.uri?authorId=56010090400>, <https://www.webofscience.com/wos/author/record/29866743>

«ACADEMIC SCIENTIFIC JOURNAL OF CHEMISTRY»

ISSN 2518-1491 (Online),

ISSN 2224-5286 (Print)

Меншіктенуші: «Орталық Азия академиялық ғылыми орталығы» ЖШС (Алматы қ.).

Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 05.06.2025 ж. берілген № KZ23VPY00121156 мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Тақырыптық бағыты: *органикалық химия, бейорганикалық химия, катализ, электрохимия және коррозия, фармацевтикалық химия және технологиялар.*

Мерзімділігі: жылына 4 рет.

<http://chemistry-technology.kz/index.php/en/arhiv>

© «Орталық Азия академиялық ғылыми орталығы» ЖШС, 2025

Редакцияның мекенжайы: 050100, Алматы қ., Қонаев к-сі, 142, «Д.В. Сокольский атындағы отын, катализ және электрохимия институты» АҚ, каб. 310, тел. 291-62-80, факс 291-57-22, e-mail:orgcat@nursat.kz

Главный редактор:

ЖУРИНОВ Мурат Журинович, доктор химических наук, профессор, академик НАН РК, президент РОО Национальной академии наук Республики Казахстан, генеральный директор АО «Институт топлива, катализа и электрохимии им. Д.В. Сокольского» (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=6602177960>, <https://www.webofscience.com/wos/author/record/2017489>

Редакционная коллегия:

АДЕКЕНОВ Сергазы Мынжасарович (заместитель главного редактора), доктор химических наук, профессор, академик НАН РК, директор Международного научно-производственного холдинга «Фитохимия» (Караганда, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=7006153118>, <https://www.webofscience.com/wos/author/record/48648658>

АГАБЕКОВ Владимир Енокович (заместитель главного редактора), доктор химических наук, профессор, академик НАН Беларуси, почетный директор Института химии новых материалов (Минск, Беларусь), <https://www.scopus.com/authid/detail.uri?authorId=7004624845>, <https://www.webofscience.com/wos/author/record/28920574>

СТРНАД Мiroслав, профессор, заведующий лабораторией института Экспериментальной ботаники Чешской академии наук (Оломоуц, Чехия), <https://www.scopus.com/authid/detail.uri?authorId=36789185000>, <https://www.webofscience.com/wos/author/record/18379>

БУРКИТБАЕВ Мухамбеткали, доктор химических наук, профессор, академик НАН РК, (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=8513885600>, <https://www.webofscience.com/wos/author/record/691218>

ХОХМАНН Джудит, заведующий кафедрой Фармакогнозии Фармацевтического факультета Университета Сегеда, директор Междисциплинарного центра естественных наук (Сегед, Венгрия), <https://www.scopus.com/authid/detail.uri?authorId=7004457196>, <https://www.webofscience.com/wos/author/record/15630788>

РОСС Самир, PhD, профессор Школы Фармации национального центра научных исследований растительных продуктов Университета Миссисипи (Оксфорд, США), <https://www.scopus.com/authid/detail.uri?authorId=7401610128>, <https://www.webofscience.com/wos/author/record/47926269>

ХУТОРЯНСКИЙ Виталий, доктор философии (Ph.D, фармацевт), профессор Университета Рединга (Рединг, Англия), <https://www.scopus.com/authid/detail.uri?authorId=35606915700>, <https://www.webofscience.com/wos/author/record/221621>

ТЕЛЫТАЕВ Багдат Бурханбайулы, доктор технических наук, профессор, академик НАН РК, Министерство Индустрии и инфраструктурного развития Республики Казахстан (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=6506225641>, <https://www.webofscience.com/wos/author/record/72161>

ФАРУК Ахсана Дар, профессор колледжа Восточной медицины Хамдарда аль-Маджида, факультет Восточной медицины университета Хамдарда (Карачи, Пакистан), <https://www.scopus.com/authid/detail.uri?authorId=55884056900>, <https://www.webofscience.com/wos/author/record/1796996>

ФАЗЫЛОВ Серик Драхметович, доктор химических наук, профессор, академик НАН РК, заместитель директора по научной работе Института органического синтеза и углехимии (Караганда, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=6701472056>, <https://www.webofscience.com/wos/author/record/1541357>

ЖОРОБЕКОВА Шарипа Жоробековна, доктор химических наук, профессор, академик НАН Кыргызстана, Институт химии и химической технологии НАН КР (Бишкек, Кыргызстан), <https://www.scopus.com/authid/detail.uri?authorId=6602652060>, <https://www.webofscience.com/wos/author/record/31723468>

ХАЛИКОВ Джурабай Халикович, доктор химических наук, профессор, академик АН Таджикистана, Институт химии имени В.И. Никитина АН РТ (Душанбе, Таджикистан), <https://www.scopus.com/authid/detail.uri?authorId=6603735641>, <https://www.webofscience.com/wos/author/record/9567106>

ФАРЗАЛИЕВ Вагиф Меджид оглы, доктор химических наук, профессор, академик НАНА (Баку, Азербайджан), <https://www.scopus.com/authid/detail.uri?authorId=6601962486>, <https://www.webofscience.com/wos/author/record/21617033>

ГАРЕЛИК Хемда, доктор философии (Ph.D, химия), президент Отдела химии и окружающей среды Международного союза чистой и прикладной химии (Лондон, Англия), <https://www.scopus.com/authid/detail.uri?authorId=56010090400>, <https://www.webofscience.com/wos/author/record/29866743>

«ACADEMIC SCIENTIFIC JOURNAL OF CHEMISTRY».

ISSN 2518-1491 (Online),

ISSN 2224-5286 (Print)

Собственник: Республиканское общественное объединение ТОО «Центрально-азиатский академический научный центр» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан № KZ23VPY00121156, выданное 05.06.2025 г.

Тематическая направленность: *органическая химия, неорганическая химия, катализ, электрохимия и коррозия, фармацевтическая химия и технологии.*

Периодичность: 4 раз в год.

<http://chemistry-technology.kz/index.php/en/arhiv>

© ТОО «Центрально-азиатский академический научный центр», 2025

Адрес редакции: 050100, г. Алматы, ул. Кунаева, 142, АО «Институт топлива, катализа и электрохимии им. Д.В. Сокольского», каб. 310, тел. 291-62-80, факс 291-57-22, e-mail:orgcat@nursat.kz

CONTENTS

G.E. Azimbayeva, A.K. Kamysbayeva, G.N. Kudaibergenova, U.Zh. Beysenbiyeva, N.M. Kurbanbayeva Chromatographic analysis of ethanol obtained from topinambur tubers (<i>Helianthus Tuberosus</i>).....	13
B. Amiraliyev, N. Zhanikulov, B. Taimasov, M. Aitureev, B. Zhakipbayev Expanding the raw material base of mineral additives for the production of composite cements.....	27
A.M. Yegissinova, R.S. Taubayeva, R.K. Rakhmetullaeva, A.S. Seitkan, E.B. Satkozhaeva Physicochemical properties of thermoplastic starch/hemp biofilm produced by casting method.....	41
E.M. Yergaliyeva, K.B. Bazhykova, Zh.Zh. Kolbaeva, A. Duysen, V.V. Vazhev <i>In silico</i> prediction of PASS and ADME/Tox properties of novel 1,3,5-triazine derivatives for drug development.....	54
R.I. Jalmakhanbetova, S. Azatkyzy, G.K. Mukusheva Structure-directed ursolic acid modifications and their impact on biological activity.....	71
R.N. Zhanaliyeva, B.S. Imangaliyeva, M.A. Zharkınbekov, A.S. Ungarbayeva, R. Kozykeyeva Study of the kinetics and mechanism of molybdenum disulfide oxidation by sodium hypochlorite.....	87
O.S. Ilyassova, M. Zhumabek, G.N. Kaumenova, R.S. Orazbekova, B.S. Biyekeyev Hydrogenation of carbon dioxide on Ni-Co/ZrO ₂ catalysts for conversion into synthetic fuel components.....	100
K. Kalmakov, G. Turebekova, S. Yegemberdiyeva, U. Nuridinova, N. Dulat Catalytic cracking of vacuum gas oil from Kumkol oil in a fluidized bed catalyst unit.....	115
B.T. Kuderina, N.B. Kassenova, A.S. Khamitova, A.G. Zhaxybayeva, A.B. Abdrakhmanova Modification of the structure of oxide cathode materials to enhance the capacity and stability of li - ion batteries.....	128

B.M. Kaldybaeva, D.M. Kenzhebekov, D.Zh. Janabayev, L.M. Ulyev, A. Zholshybek Improving the energy efficiency of oil treatment and stabilization units in the field.....	137
A.K. Kozybaev, Zh.D. Alimkulova, S.O. Abilkasova, G.O. Bugubaeva, S. Bubish Prospects for the use of water-soluble copolymers in industrial wastewater treatment processes.....	150
R.M. Kudaibergenova, A.R. Aitekova, N.S. Murzakasymova, A.S. Seitkan, N.A. Nurlybayeva Structural and compositional characteristics of cobalt ferrite nanoparticles.....	159
M. Nazhipkyzy, A. Ashiraly, A. Aitugan, A. Aikenova Fabrication of lignin-based fibrous composites by electrospinning for energy storage applications.....	170
U. Nazarbek, Y. Raiymbekov, P. Abdurazova, G. Kambarova Molecular dynamics modeling of solubility in aqueous systems: temperature dependence and solvation effects.....	184
Zh.Zh. Nurtazina, Zh.S. Kassymova, L.K. Orazzhanova, B. Łeska, N.B. Kiarstanova Efficiency of modified medium for pigment and antioxidant biosynthesis in <i>Chlorella Vulgaris</i>	197
G.M. Ormanova, A.A. Anarbayev, B.N. Kabylbekova, Zh.E. Khusanov Construction of a solubility isotherm in a four-component mutual CaSO ₄ -NaCl-H ₂ O system.....	212
Zh.B. Rakhimberlinova, A. Zhorabek, A. Bailen, M. Kaiyrbaeva, A. Mendibayeva Investigation of the possibilities of obtaining ultradispersed copper particles in aqueous solutions.....	227
A. Takibayeva, L. Sultanova, A. Tussupova, Z. Omar, A. Amanzholova Mechanism, features of the amination reaction in a series of lupane triterpenoids.....	239
G. Toleutay, R.N. Tuleyeva, A. Taubatyrova, N.N. Gizatullina Recent advances in the application of lignin for biobased packaging materials.....	250
Kh. Khimersen, T.K. Jumadilov, A. Imangazy, G.T. Dyusseмбаeva, B. Totkhuskyzy Features of the interaction of polyelectrolytes with gallium ions in aqueous media.....	266

МАЗМҰНЫ

Г.Е. Азимбаева, А.К. Камысбаева, Г.Н. Кудайбергенова, Ұ.Ж. Бейсенбиева, Н.М. Курбанбаева Топинамбур жемісінен (<i>Helianthus Tuberosus</i>) алынған этанолдың хроматографиялық анализі.....	13
Б. Амиралиев, Н. Жаникулов, Б. Таймасов, М. Айтуреев, Б. Жакипбаев Композициялық цемент алу үшін минералды қоспалардың шикізат базасын кеңейту.....	27
А.М. Егисина, Р.С. Таубаева, Р.К. Рахметуллаева, А.С. Сейткан, Э.Б. Саткожаева Құю әдісі арқылы алынған термопластикалық крахмал/ конопля биопленкасының физика-химиялық қасиеттері.....	41
Э.М. Ергалиева, К.Б. Бажыкова, Ж.Ж. Кольбаева, А.Б. Дуйсен, В.В. Важев <i>In silico</i> PASS және ADME/Tox бағдарламалары арқылы дәрілік заттар әзірлеу үшін 1,3,5-триазиннің жаңа туындыларының қасиеттерін болжау.....	54
Р.И. Джалмаханбетова, С. Азатқызы, Г.К. Мукушева Урсол қышқылының құрылымдық-бағытталған модификациялары және олардың биологиялық белсенділікке әсері.....	71
Р.Н. Жаналиева, Б.С. Имангалиева, М.А. Жаркинбеков, А.С. Унгарбаева, Р. Қозыкеева Молибден дисульфидін натрий гипохлоритімен тотықтырудың кинетикасы мен механизмін зерттеу.....	87
О.С. Ильясова, М. Жумабек, Г.Н. Кауменова, Р.С. Оразбекова, Б.С. Биекеев Көмірқышқыл газын синтетикалық отын компоненттеріне айналдыру үшін Ni-Co/ZrO ₂ катализаторларында гидрлеу.....	100
К.К. Калмаков, Г.З. Туребекова, С.Ж. Егембердиева, У.Е. Нуридинова, Н.Н. Дулат Құмкөл мұнайынан алынған вакуум газойлін катализатордың қайнау қабатындағы қондырғыда каталитикалық крекингтеу.....	115
Б.Т. Кудерина, Н.Б. Касенова, А.С. Хамитова, А.Г. Жаксыбаева, А.Б. Абдрахманова Li - ионды аккумуляторлардың сыйымдылығы мен тұрақтылығын арттыру үшін оксидті катод материалдарын модификациялау.....	128

Б.М. Калдыбаева, Д.М. Кенжебеков, Д.Ж. Джанабаев, Л.М. Ульев, А. Жолшыбек Кәсіпшілікте мұнайды дайындау және тұрақтандыру қондырғысының энергия тиімділігін арттыру.....	137
А.Қ. Қозыбаев, Ж.Д. Әлімқұлова, С.О. Әбілқасова, Г.О. Бугубаева, Ш. Бүбіш Өндірістік ағынды суларды тазарту процестерінде суда еритін сополимерлерді қолдану перспективалары.....	150
Р.М. Құдайбергенова, А.Р. Айтекова, Н.С. Мурзакасымова, А.С. Сейтқан, А.Н. Нұрлыбаева Кобалт феррит нанобөлшектерінің құрылымдық және құрамдық сипаттамасы.....	159
М. Нажипқызы, А. Ашіралы, А. Айтуған, А. Айкенова Энергия сақтау жүйелерінде қолдануға арналған лигнин негізіндегі талшықты композиттерді электроспиннинг әдісімен алу.....	170
У. Назарбек, Е. Райымбеков, П. Абдуразова, Ғ. Қамбарова Су жүйелеріндегі ерігіштіктің молекулалық динамикалық модельдеуі: температураға тәуелділік және еріткіштің әсері.....	184
Ж.Ж. Нуртазина, Ж.С. Касымова, Л.К. Оразжанова, Л. Богуслава, Н.Б. Қиарстанова <i>Chlorella Vulgaris</i> құрамындағы пигменттер мен антиоксиданттардың биосинтезі үшін модификацияланған қоректік ортаның тиімділігі.....	197
Г.М. Орманова, А.А. Анарбаев, Б.Н. Кабылбекова, Ж.Е. Хусанов Төрт компонентті CASO ₄ -NaCl-H ₂ O өзара әрекеттесу жүйесіндегі ерігіштік изотермасын тұрғызу.....	212
Ж.Б. Рахимберлинова, А. Жорабек, А. Байлен, М. Қайырбаева, Ә. Мендібаева Сулы ерітінділердегі мыстың ультродисперсті бөлшектерін алу мүмкіндіктерін зерттеу.....	227
А. Такибаева, Л. Султанова, А. Тусупова, З. Омар, А. Аманжолова Лупан тритерпеноидтар қатарындағы аминдену реакциясының механизмі, ерекшеліктері.....	239

Г. Төлеутай, Р.Н. Тулеева, А. Таубатырова, Н.Н. Гизатуллина

Лигниннің бионегізді қаптама материалдарында қолданылуының

соңғы жетістіктері.....250

Х. Химэрсэн, Т.К. Джумадилов, А. Имангазы, Г.Т. Дюсембаева,

Б. Тотхусқызы

Полиэлектролиттердің галлий иондарымен су ортасында әрекеттесу

ерекшеліктері.....266

СОДЕРЖАНИЕ

Г.Е. Азимбаева, А.К. Камысбаева, Г.Н. Кудайбергенова, У.Ж. Бейсенбиева, Н.М. Курбанбаева Хроматографический анализ этанола полученного из клубней топинамбура (<i>Helianthus Tuberosus</i>).....	13
Б. Амиралиев, Н. Жаникулов, Б. Таймасов, М. Айтурсев, Б. Жакипбаев Расширение сырьевой базы минеральных добавок для получения композиционных цементов.....	27
А.М. Егисинова, Р.С. Таубаева, Р.К. Рахметуллаева, А.С. Сейткан, Э.Б. Саткожаева Физико-химические свойства термопластичной биопленки из крахмала/конопли, полученной методом литья.....	41
Э.М. Ергалиева, К.Б. Бажыкова, Ж.Ж. Кольбаева, А.Б. Дуйсен, В.В. Важев IN SILICO PASS и ADME/TOX прогнозирование свойств новых производных 1,3,5-триазина для разработки лекарств.....	54
Р.И. Джалмаханбетова, С. Азаткызы, Г.К. Мукушева Структурно-направленные модификации урсоловой кислоты и их влияние на биологическую активность.....	71
Р.Н. Жаналиева, Б.С. Имангалиева, М.А. Жаркинбеков, А.С. Унгарбаева, С. Бердібекова Изучение кинетики и механизма окисления дисульфида молибдена гипохлоритом натрия.....	87
О.С. Ильясова, М. Жумабек, Г.Н. Кауменова, Р.С. Оразбекова, Б.С. Биекеев Гидрирование диоксида углерода на Ni-Co/ZrO ₂ катализаторах для преобразования в компоненты синтетического топлива.....	100
К.К. Калмаков, Г.З. Туребекова, С.Ж. Егембердиева, У.Е. Нуридинова, Н.Н. Дулат Каталитический крекинг вакуумного газойля Кумкольской нефти на установке псевдоожиженным слоем катализатора.....	115
Б.Т. Кудерина, Н.Б. Касенова, А.С. Хамитова, А.Г. Жаксыбаева, А.Б. Абдрахманова Модификация структуры оксидных катодных материалов для повышения ёмкости и стабильности Li-ион аккумуляторов.....	128

Б.М. Калдыбаева, Д.М. Кенжебеков, Д.Ж. Джанабаев, Л.М. Ульев, А. Жолшыбек Повышение энергоэффективности установки подготовки и стабилизации нефти на промысле.....	137
А.К. Козыбаев, Ж.Д. Алимкулова, С.О. Абилкасова, Г.О. Бугубаева, Ш. Бубиш Перспективы использования водорастворимых сополимеров в процессах очистки промышленных сточных вод.....	150
Р.М. Кудайбергенова, А.Р. Айтекова, Н.С. Мурзакасымова, А. Сейткан, А.Н. Нурлыбаева Структурно-композиционные характеристики наночастиц феррита кобальта.....	159
М. Нажипкызы, А. Аширалы, А. Айтуган, А. Айкенова Получение волокнистых композитов на основе лигнина методом электроспиннинга для применения в системах хранения энергии.....	170
У. Назарбек, П. Абдуразова, Ғ. Қамбарова, Е. Райымбеков Молекулярно-динамическое моделирование растворимости в водных системах: температурная зависимость и эффекты сольватации.....	184
Ж.Ж. Нуртазина, Ж.С. Касымова, Л.К. Оразжанова, Л. Богуслава, Н.Б. Қиарстанова Эффективность модифицированной среды для биосинтеза пигментов и антиоксидантов в <i>Chlorella Vulgaris</i>	197
Г.М. Орманова, А.А. Анарбаев, Б.Н. Кабылбекова, Ж.Е. Хусанов Построение изотермы растворимости в четырехкомпонентной взаимной системе $\text{CaSO}_4\text{-NaCl-H}_2\text{O}$	212
Ж.Б. Рахимберлинова, А. Жорабек, А. Байлен, М. Кайырбаева, А. Мендибаева Исследование возможностей получения ультрадисперсных частиц меди в водных растворах.....	227
А. Такибаева, Л. Султанова, А. Тусупова, З. Омар, А. Аманжолова Механизм, особенности протекания реакции аминирования в ряду лупановых тритерпеноидов.....	239

Г. Толеутай, Р.Н. Тулеева, А. Таубатырова, Н.Н. Гизатуллина

Последние достижения в применении лигнина для биополимерных

упаковочных материалов.....250

Х. Химэрсэн, Т.К. Джумадилов, А. Имангазы, Г.Т. Дюсембаева,

Б. Тотхусқызы

Особенности взаимодействие полиэлектролитов с ионами галлия

в водной среде.....266

© **R.M. Kudaibergenova***, **A.R. Aitekova** , **N.S. Murzakasymova**, **A.S. Seitkan**,
N.A. Nurlybayeva, 2025.

M.Kh. Dulaty Taraz University, Taraz, Kazakhstan.

*E-mail: rm.kudajbergenova@dulaty.kz

STRUCTURAL AND COMPOSITIONAL CHARACTERISTICS OF COBALT FERRITE NANOPARTICLES

Kudaibergenova Rabiga — PhD, M.Kh. Dulaty Taraz University, Taraz, Kazakhstan,

E-mail: rm.kudajbergenova@dulaty.kz, <https://orcid.org/0000-0003-0759-1539>;

Aitekova Anar — PhD student, M.Kh. Dulaty Taraz University, Taraz, Kazakhstan,

E-mail: ar.aitekova@dulaty.kz, <https://orcid.org/0009-0006-9992-0043>;

Murzakasymova Nazgul — PhD, M.Kh. Dulaty Taraz University, Taraz, Kazakhstan,

E-mail: ns.murzakasymova@dulaty.kz, <https://orcid.org/0000-0003-0329-6137>;

Seitkan Ainur — candidate of technical sciences, L.N. Gumilyov Eurasian National University, Astana, Kazakhstan,

E-mail: seitkan_as@enu.kz, <https://orcid.org/0000-0001-9309-500X>;

Nurlybayeva Aisha — PhD, Associate Professor, M.Kh. Dulaty Taraz University, Kazakhstan,

E-mail: a.nurlybayeva@dulaty.kz, <https://orcid.org/0000-0001-9904-9979>.

Abstract. Spinel ferrites, particularly cobalt ferrite (CoFe_2O_4), have gained increasing scientific attention due to their multifunctional physicochemical properties and wide applicability in catalysis, sensing, magnetic storage, and environmental remediation. Their stable magnetic behavior, variable oxidation states, high permeability, and strong electrochemical stability make CoFe_2O_4 a promising material for advanced technological applications. The growing need for efficient, recyclable, and environmentally friendly materials for wastewater treatment further enhances the relevance of cobalt ferrite as a magnetic adsorbent and catalyst. The aim of this study is to synthesize phase-pure CoFe_2O_4 nanoparticles and investigate their structural and physicochemical characteristics to assess their potential for environmental applications. CoFe_2O_4 nanoparticles were synthesized using the sol–gel combustion technique. Structural and chemical analyses were performed using X-ray diffraction (XRD), energy-dispersive X-ray spectroscopy (EDS), and Fourier-transform infrared spectroscopy (FTIR). XRD confirmed the formation of a single-phase spinel cobalt ferrite structure (ICSD 1533163, space group $\text{Fd}\bar{3}\text{m}$). EDS analysis revealed only cobalt, iron, and oxygen elements, indicating high purity, while FTIR spectra exhibited characteristic absorption bands

corresponding to tetrahedral and octahedral metal–oxygen vibrations. The synthesized CoFe_2O_4 exhibited the typical spinel lattice with cation distribution $(\text{Fe}^{3+})_a(\text{Co}^{2+}\text{Fe}^{3+})_\beta\text{O}_4$, which imparts high structural stability, catalytic activity, strong saturation magnetization, low solubility of metal ions, and a relatively large surface area. These features highlight the practical significance of CoFe_2O_4 nanoparticles for environmental applications, particularly in wastewater treatment technologies, where their magnetic nature allows efficient recovery and reuse, improving both sustainability and operational efficiency.

Keywords: cobalt ferrite nanoparticles, spinel, sol-gel, X-ray diffraction, EDS, FTIR

Financing. *This research was conducted as part of the targeted funding program for the project IRN BR24992867, titled “Development of resource-saving technologies for the development and management of the water sector and processing industry in Kazakhstan, establishment of an innovative engineering center”.*

© Р.М. Құдайбергенова*, А.Р. Айтекова, Н.С. Мурзакасымова, А.С. Сейткан, А.Н. Нурлыбаева, 2025.

М.Х. Дулати атындағы Тараз университеті, Тараз, Қазақстан.

*E-mail: rm.kudajbergenova@dulaty.kz

КОБАЛТ ФЕРРИТ НАНОБӨЛШЕКТЕРІНІҢ ҚҰРЫЛЫМДЫҚ ЖӘНЕ ҚҰРАМДЫҚ СИПАТТАМАСЫ

Құдайбергенова Рабиға — PhD, М.Х. Дулати атындағы Тараз университеті, Тараз, Қазақстан,
E-mail: rm.kudajbergenova@dulaty.kz, <https://orcid.org/0000-0003-0759-1539>;

Айтекова Анар — PhD, М.Х. Дулати атындағы Тараз университеті, Тараз, Қазақстан,
E-mail: ar.aitekova@dulaty.kz, <https://orcid.org/0009-0006-9992-0043>;

Мурзакасымова Назгүл — PhD, М.Х. Дулати атындағы Тараз университеті, Тараз, Қазақстан,
E-mail: ns.murzakasymova@dulaty.kz, <https://orcid.org/0000-0003-0329-6137>;

Сейткан Айнұр — техника ғылымдарының кандидаты, Л.Н. Гумилев атындағы Еуразия ұлттық университеті, Астана, Қазақстан,
E-mail: seitkan_as@enu.kz, <https://orcid.org/0000-0001-9309-500X>;

Нурлыбаева Айша — PhD, қауымдастырылған профессор, М.Х. Дулати атындағы Тараз университеті, Тараз, Қазақстан,
E-mail: a.nurlybayeva@dulaty.kz, <https://orcid.org/0000-0001-9904-9979>.

Аннотация. Шпинель ферриттері, әсіресе кобальт ферриті (CoFe_2O_4), кең функционалдық қасиеттері мен қолдану мүмкіндіктеріне байланысты ғылыми тұрғыдан үлкен қызығушылық тудырып отыр. Оның тұрақты магниттік қасиеттері, тотығу дәрежесінің өзгергіштігі, жоғары өткізгіштігі және электрохимиялық тұрақтылығы CoFe_2O_4 материалын сенсорлар, катализаторлар, магнитті тасымалдағыштар және қоршаған ортаны қорғау технологиялары үшін перспективалы етеді. Тұрмыстық және өндірістік ағынды суларды тиімді әрі қайта пайдалануға жарамды материалдармен тазарту қажеттілігі бұл материалдың өзектілігін арттыра түседі. Зерттеудің мақсаты – таза фазалы CoFe_2O_4 нанобөлшектерін синтездеу және олардың құрылымдық-физика-химиялық

қасиеттерін анықтап, экологиялық қолдануға жарамдылығын бағалау. CoFe_2O_4 нанобөлшектері золь - гель жану әдісімен синтезделді. Үлгілердің құрылымы мен құрамы рентгендік дифракция (XRD), энергия дисперсиялық рентгендік спектроскопия (EDS) және Фурье түрлендіру инфрақызыл спектроскопиясы (FTIR) әдістерімен зерттелді. XRD нәтижелері CoFe_2O_4 -тің бірфазалы шпинель құрылымда түзілгенін (ICSD 1533163, $\text{Fd}\bar{3}\text{m}$) көрсетті. EDS талдауы құрамда тек кобальт, темір және оттегінің бар екенін анықтады, ал FTIR спектрі шпинель торына тән металл - оттегі тербеліс жолақтарын көрсетті. Алынған $\text{CoFe}_2\text{O}_4 (\text{Fe}^{3+})_a (\text{Co}^{2+}\text{Fe}^{3+})_b \text{O}_4$ типті шпинель торымен сипатталады. Мұндай құрылым материалға жоғары құрылымдық тұрақтылық, қанығу магниттелгіштігі, каталитикалық белсенділік, металл иондарының төмен ерігіштігі және салыстырмалы үлкен беткі аудан береді. Бұл қасиеттер CoFe_2O_4 нанобөлшектерін ағынды суларды тазарту саласында магнитті адсорбент немесе катализатор ретінде қолдануға өте қолайлы материал етеді, сонымен бірге оның магниттік табиғаты бөлшектерді оңай бөлуге және қайта пайдалануға мүмкіндік береді.

Түйін сөздер: кобальт феррит нанобөлшектері, шпинель, золь - гель, рентгендік дифракция, EDS, FTIR

© Р.М. Кудайбергенова *, А.Р. Айтекова, Н.С. Мурзакасымова,
А. Сейткан, А.Н. Нурлыбаева, 2025.

Таразский университет имени М.Х. Дулати, Тараз, Казахстан.

*E-mail: rm.kudajbergenova@dulaty.kz

СТРУКТУРНО-КОМПОЗИЦИОННЫЕ ХАРАКТЕРИСТИКИ НАНОЧАСТИЦ ФЕРРИТА КОБАЛЬТА

Кудайбергенова Рабига — PhD, Таразский университет имени М.Х. Дулати, Тараз, Казахстан,

E-mail: rm.kudajbergenova@dulaty.kz, <https://orcid.org/0000-0003-0759-1539>;

Айтекова Анар — PhD, Таразский университет имени М.Х. Дулати, Тараз, Казахстан,

E-mail: ar.aitekova@dulaty.kz, <https://orcid.org/0009-0006-9992-0043>;

Мурзакасымова Назгуль — PhD, Таразский университет имени М.Х. Дулати, Тараз, Казахстан,

E-mail: ns.murzakasymova@dulaty.kz, <https://orcid.org/0000-0003-0329-6137>;

Сейткан Айнур — кандидат технических наук, Евразийский национальный университет им. Л.Н. Гумилёва, Астана, Казахстан,

E-mail: seitkan_as@enu.kz, <https://orcid.org/0000-0001-9309-500X>;

Нурлыбаева Айша — PhD, ассоциированный профессор, Таразский университет имени М.Х. Дулати, Тараз, Казахстан,

E-mail: a.nurlybayeva@dulaty.kz, <https://orcid.org/0000-0001-9904-9979>.

Аннотация: Шпинельные ферриты, особенно кобальтферрит (CoFe_2O_4), относятся к группе магнитных материалов, обладающих широким спектром функциональных свойств и значительным потенциалом прикладного

использования. Благодаря стабильной магнитной структуре, изменяемой валентности катионов, высокой магнитной проницаемости и электрохимической стойкости CoFe_2O_4 рассматривается как перспективный материал для сенсорных устройств, каталитических процессов, магнитных носителей и экологических технологий. На фоне растущей потребности в эффективных и регенерируемых материалах для очистки сточных вод исследование кобальтферрита приобретает особую актуальность. Цель настоящей работы заключалась в синтезе однофазных наночастиц CoFe_2O_4 и исследовании их структурных и физико-химических характеристик для оценки возможного применения в задачах экологической ремедиации. Наночастицы были получены методом золь-гель горения, обеспечивающим равномерность структуры и контролируемое формирование кристаллической фазы. Структурный анализ, выполненный методами рентгеновской дифракции (XRD), энергодисперсионной спектроскопии (EDS) и Фурье ИК-спектроскопии (FTIR), подтвердил формирование чистой шпинельной фазы CoFe_2O_4 без примесных образований. XRD-анализ выявил характерную кубическую структуру шпинели; EDS-анализ показал присутствие только элементов Co, Fe и O; FTIR-спектры продемонстрировали типичные вибрационные полосы металло-кислородных связей. Полученные наночастицы обладают типичной шпинельной конфигурацией $(\text{Fe}^{3+})_a(\text{Co}^{2+}\text{Fe}^{3+})_b\text{O}_4$, обеспечивающей высокую структурную стабильность, значительную намагниченность насыщения, низкую растворимость ионов металлов и развитую удельную поверхность. Совокупность данных свойств делает кобальтферрит CoFe_2O_4 перспективным наноматериалом для применения в очистке сточных вод и экологических систем.

Ключевые слова: наночастицы феррит кобальта, шпинель, золь-гель, рентгеновская дифракция, EDS, FTIR

Introduction. Ferrites are an important class of ceramic compounds, in which iron oxides combine with various metallic cations to form materials of great technological significance (Jeseentharani et al., 2012; Sugurbekova et al., 2024). Their distinctive ferrimagnetic behavior originates from the ordered distribution of cations within the spinel lattice, which largely determines their electrical, magnetic, and catalytic properties. The general composition of spinel ferrites can be expressed as AB_2O_4 , where divalent cations typically occupy tetrahedral (A) sites, while trivalent cations reside at octahedral (B) positions (Chae et al., 2004; Estrada et al., 2017). Among these materials, cobalt ferrite (CoFe_2O_4) has gained particular attention because of its distinctive combination of high coercivity, moderate saturation magnetization, strong magnetocrystalline anisotropy, and mechanical hardness (Koseoglu et al., 2008; Kandasamy et al., 2018).

Among spinel ferrites, cobalt ferrite (CoFe_2O_4) has emerged as one of the most promising candidates because it combines moderate saturation magnetization with high coercivity, mechanical hardness, and strong magnetocrystalline anisotropy. Unlike many other ferrites, cobalt ferrite generally adopts an inverse spinel structure in which most Co^{2+} cations occupy octahedral B-sites, while Fe^{3+} ions are distributed across both A- and B-sites. This cationic arrangement results in ferrimagnetism, where opposing spin

orientations of cobalt and iron ions generate a net magnetic moment. The combination of magnetic hardness with chemical and thermal stability renders CoFe_2O_4 particularly attractive for applications in devices that require both durability and reliable magnetic performance.

Traditionally, cobalt ferrite has been utilized in magnetic sensors, inductors, transformers, and data storage media. However, advances in nanotechnology have significantly broadened its potential. Reducing the particle size to the nanoscale alters the structural, electronic, and magnetic properties, often enhancing coercivity, surface reactivity, and catalytic performance. Nanosized CoFe_2O_4 exhibits a high surface-to-volume ratio, defect-rich structures, and cation redistribution, all of which contribute to improved functional performance compared to bulk counterparts. As a result, cobalt ferrite nanoparticles have become central to research in materials science and engineering.

In recent years, considerable attention has been directed toward biomedical uses of cobalt ferrite nanoparticles. Their strong magnetic response, biocompatibility, and ability to be guided by external magnetic fields make them suitable for targeted drug delivery, hyperthermia treatment of cancer, and as contrast agents in magnetic resonance imaging. At the same time, CoFe_2O_4 is being actively investigated for energy-related applications. Studies have shown its potential as an electrode material in lithium-ion batteries, supercapacitors, and as a catalyst in solar and fuel cells. Its combination of electrical conductivity, stability, and catalytic efficiency allows it to contribute to energy conversion and storage technologies that are vital for sustainable energy solutions.

Environmental protection is another critical area where cobalt ferrite has demonstrated great promise. CoFe_2O_4 nanoparticles can effectively adsorb heavy metals and degrade organic contaminants in wastewater (Cai et al., 2020; Al-Harbi et al., 2022). Their magnetic nature allows for simple separation and recovery, minimizing secondary pollution and enabling multiple cycles of reuse. Furthermore, cobalt ferrite functions as a robust catalyst in pollutant degradation and emission control (Yin et al., 2017; Nadeem et al., 2022).

The properties of cobalt ferrite are strongly dependent on synthesis conditions and particle morphology. Techniques such as sol–gel combustion, hydrothermal processing, and co-precipitation have been employed to produce nanoparticles with controlled size, crystallinity, and purity. Sol–gel synthesis, in particular, is widely used because it ensures homogeneity and allows tuning of microstructural features. Structural and chemical analyses, including X-ray diffraction, energy-dispersive X-ray spectroscopy, and Fourier-transform infrared spectroscopy, consistently confirm the successful formation of single-phase CoFe_2O_4 with spinel symmetry. The ability to correlate synthesis parameters with structural and magnetic properties is essential for tailoring materials to specific applications.

Given its multifunctional character, cobalt ferrite is now recognized as a material at the intersection of magnetism, catalysis, energy storage, and environmental remediation. Its stable crystal structure, high magnetic performance, large surface area, and chemical durability provide a foundation for diverse applications across industrial

and ecological fields. With continued advances in nanostructuring, surface modification, and eco-friendly synthesis approaches, CoFe_2O_4 nanoparticles are expected to play an increasingly important role in addressing global challenges such as sustainable energy production, clean water supply, and pollution control. Therefore, understanding the synthesis, structural characteristics, and functional behavior of cobalt ferrite remains a vital research direction that can contribute to the development of innovative and sustainable technologies.

Materials and methods. Materials: Iron (III) nitrate nonahydrate, purity $\geq 99.9\%$, cobalt (II) acetylacetonate, purity $\geq 95.0\%$ (Sigma-Aldrich). All precursors were of analytical grade and were used without prior treatment.

Methods: X-ray diffraction analysis was performed on a DRON-3 automatic diffractometer with $\text{CuK}\alpha$ radiation and a β -filter. Conditions for obtaining diffraction patterns: $U = 35 \text{ kV}$; $I = 20 \text{ mA}$; θ - 2θ survey; detector 2 degrees/min .

EDS analysis was performed on a Zeiss Crossbeam 540- FE-SEM scanning electron microscope. Crossbeam 540 is a dual-beam FIB- SEM microscope for nanotomography and nanofabrication, which allows EDS studies.

Preparation of the CoFe_2O_4 nanoparticles.

The synthesis of CoFe_2O_4 nanoparticles was carried out using a sol-gel route. Iron(III) nitrate nonahydrate (3.308 g, 8 mmol) and cobalt(II) acetylacetonate (0.996 g, 4 mmol) were employed as metal precursors. The salts were dissolved in ethanol and placed in a three-neck flask equipped with a condenser, followed by heating under magnetic stirring. After 10 min of heating, 1 ml of acetic acid was introduced as a catalyst to promote hydrolysis. Subsequently, 1 ml of 2-methoxyethanol was added as a co-solvent after 20 min. Additional reagents, including distilled water, ethylene glycol, and ethanol, were then incorporated into the reaction mixture, and continuous stirring was maintained until gel formation was achieved. The resulting gels were dried at 100°C for 24 h to remove residual solvents and organic components. Finally, the dried samples were calcined in a muffle furnace at 600°C for 8 h to obtain crystalline cobalt ferrite nanoparticles.

Results and discussions. X-ray diffraction analysis was performed to verify the phase formation of cobalt ferrite nanoparticles (Figure 1). The diffraction pattern exhibited peaks that can be exclusively indexed to the spinel CoFe_2O_4 structure (ICSD 1533163, space group $\text{Fd}3\text{m}$), confirming that the synthesis procedure yielded a pure single-phase material. These results are consistent with the classical structural data reported by Shannon et al. (1976) and demonstrate successful formation of the spinel lattice. The calculated average crystallite size was approximately 35 nm, as estimated from the broadening of diffraction peaks, which is a typical feature of nanocrystalline materials. The observed crystallite size is in good agreement with values reported in recent studies of sol-gel synthesized CoFe_2O_4 . For example, Kandasamy et al. (2018) and Al-Harbi et al. (2022) reported crystallite sizes in the range of 25–40 nm, depending on synthesis conditions and calcination temperatures. Similarly, Cai et al. (2020) observed that the crystallite size of cobalt ferrite nanoparticles could be tuned between 20 and 45 nm by modifying the solvent composition during the sol-gel process. The 35 nm crystallite

size obtained in this work thus falls within the typical range and confirms that the chosen synthesis parameters provide controlled nanostructure formation. Furthermore, the phase purity observed in the XRD pattern is particularly important, as secondary phases such as Fe_2O_3 or CoO are often reported when synthesis parameters are not carefully optimized (Yin et al., 2017; Nadeem et al., 2022). The absence of such impurity peaks in our results highlights the effectiveness of the applied sol-gel combustion route in producing phase-pure cobalt ferrite. This structural purity is critical for ensuring reproducible magnetic and catalytic performance in subsequent applications, as even minor impurity phases can significantly alter the overall physicochemical properties of the material.

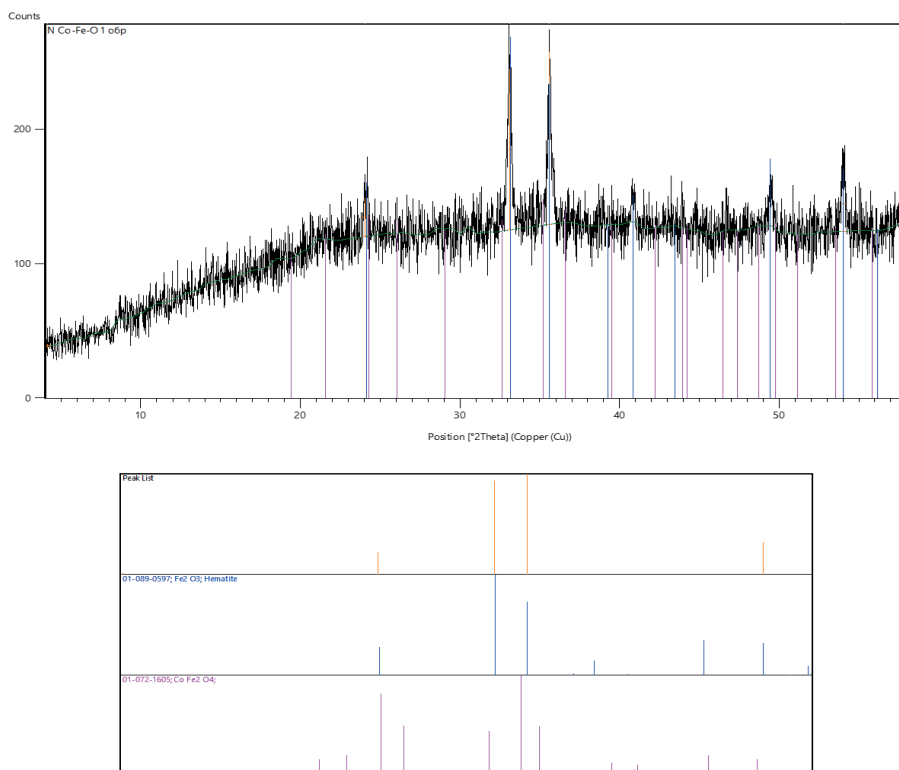


Figure 1 - X-ray diffraction analysis of CoFe_2O_4 nanoparticles.

The energy-dispersive X-ray spectroscopy (EDS) analysis of the synthesized CoFe_2O_4 nanoparticles is shown in Figure 2. The obtained spectrum reveals distinct peaks corresponding exclusively to cobalt, iron, and oxygen, with no detectable signals from foreign elements, thereby confirming the absence of impurities in the sample (Carta et al., 2009). The quantitative analysis further demonstrated that the elemental ratio of Co, Fe, and O was in excellent agreement with the expected stoichiometry of cobalt ferrite, verifying the high phase purity of the material. Such consistency strongly indicates the effectiveness of the sol-gel combustion approach in producing

chemically homogeneous nanoparticles. Comparable findings have been reported in recent studies, where EDS characterization also confirmed the stoichiometric accuracy and compositional uniformity of CoFe_2O_4 nanoparticles synthesized via sol–gel and solvothermal methods (Yin et al., 2017; Al-Harbi et al., 2022; Nadeem et al., 2022). These results collectively underline that the chosen synthesis technique ensures not only structural integrity but also compositional precision, which is crucial for maintaining the desired magnetic and catalytic properties of cobalt ferrite.

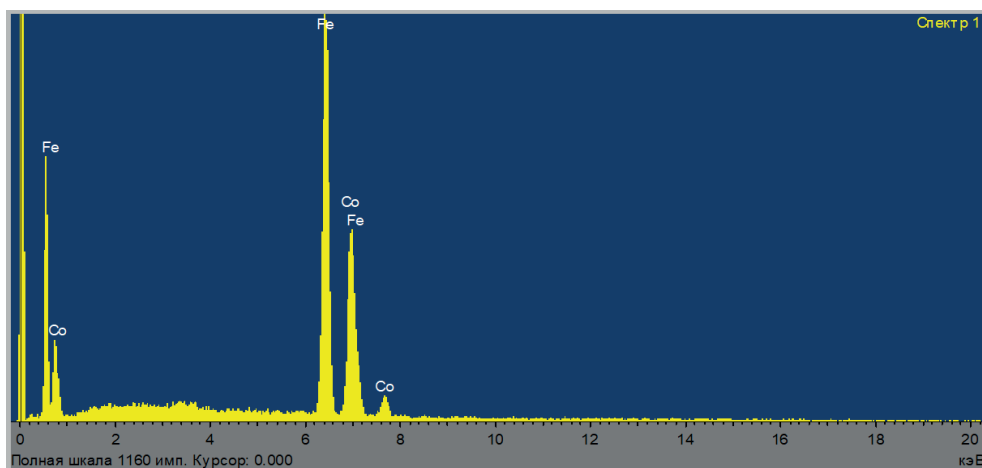


Figure 2 - EDS spectrum of CoFe_2O_4 nanoparticles.

FTIR spectroscopy was used to confirm the spinel structure of cobalt ferrite. The spectra of CoFe_2O_4 nanoparticles were recorded in the range of $4000\text{--}500\text{ cm}^{-1}$ (Figure 3). A strong absorption band at around 563 cm^{-1} is attributed to the stretching vibrations of metal–oxygen bonds in the tetrahedral and octahedral sites of the spinel lattice, clearly confirming the formation of the cobalt ferrite phase (Waldron et al., 1955). Broad bands between 3351 and 1653 cm^{-1} are associated with O–H stretching vibrations from water molecules adsorbed on the nanoparticle surface during synthesis (Thakur et al., 2023). Additional peaks observed at 1426 and 1653 cm^{-1} correspond to the symmetric and asymmetric stretching of COO^- groups, while the bands near 833 cm^{-1} and 2160 cm^{-1} are attributed to C–O and CO_2 stretching vibrations, respectively. The appearance of absorption bands in the range of $530\text{--}619\text{ cm}^{-1}$ further supports the presence of spinel-type M–O bonds: the band at 833 cm^{-1} can be linked to Co–O vibrations in octahedral positions, while the one near 530 cm^{-1} corresponds to Fe–O vibrations in tetrahedral coordination (Spizzo et al., 2016). Similar FTIR features have been reported in recent studies, where CoFe_2O_4 nanoparticles consistently exhibit two dominant metal–oxygen bands in the range of $419\text{--}577\text{ cm}^{-1}$, confirming the spinel ferrite structure (Kiani et al., 2023; Nadeem et al., 2022). These results demonstrate that the spectra obtained in this study are in good agreement with literature data and further verify the successful synthesis of stoichiometric cobalt ferrite with a well-defined spinel structure, described by the cation distribution $(\text{Fe}^{3+})\text{A}(\text{Co}^{2+}\text{Fe}^{3+})\text{BO}_4$.

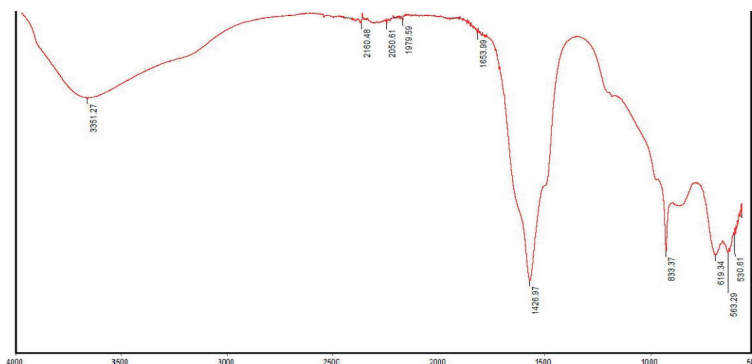


Figure 3 - FTIR spectrum of CoFe_2O_4 nanoparticles.

The magnetic properties of the synthesized sample were examined using a vibrating sample magnetometer (VSM), and the corresponding hysteresis loop is shown in Figure 4. Analysis of the magnetization curve revealed the following key parameters: coercivity of 157 Oe, remanent magnetization of 26.4 emu/g, saturation magnetization of 61 emu/g, and a squareness ratio (M_r/M_s) of 0.43. These results are characteristic of ferrimagnetic spinel-type materials and confirm the successful formation of a magnetically hard phase. The estimated crystallite size of approximately 60 nm indicates the presence of multidomain structures, which typically exhibit higher coercivity and substantial saturation magnetization (Yin et al., 2017; Patil et al., 2021).

Phase composition analysis demonstrated that the obtained powder is multicomponent, consisting mainly of spinel-type (Co, Fe) oxide ($\sim 73.6\%$), described as $(\text{Co}_{0.19}\text{Fe}_{0.81})(\text{Co}_{0.19}\text{Fe}_{0.81})\text{O}_{3.984}$, along with a secondary hematite (Fe_2O_3) phase ($\sim 26.4\%$). The dominance of the spinel fraction primarily governs the observed ferrimagnetic response, while the presence of hematite may influence the coercivity and residual magnetization values (Sarkar et al., 2019).

In addition to the quantitative VSM analysis, the magnetic response of the CoFe_2O_4 nanoparticles was qualitatively verified using a permanent magnet, as illustrated in Figure 4. The nanoparticles exhibited strong attraction to the magnetic field, further confirming their magnetic character. Such behavior makes cobalt ferrite nanoparticles promising candidates for applications in magnetic separation, catalysis, drug delivery, and environmental remediation, where efficient recovery of nanomaterials through external fields is advantageous (Kombaiah et al., 2020; Zhang et al., 2023).

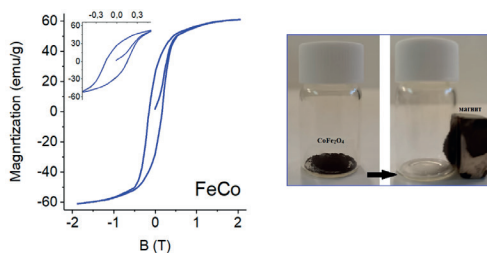


Figure 4 - Magnetic characteristics of CoFe_2O_4 nanoparticles

Among spinel-type ferrites, cobalt ferrite (CoFe_2O_4) is particularly attractive for wastewater treatment applications. Its combination of high catalytic efficiency, strong saturation magnetization, and chemically stable crystal framework makes it highly effective in pollutant degradation processes. In addition, CoFe_2O_4 demonstrates low solubility of metal ions in aqueous environments, which reduces secondary contamination risks. The material also possesses a relatively large specific surface area, enhancing its adsorption and catalytic performance. A further advantage is its facile magnetic separation from treated water, allowing simple recovery and reuse, which is critical for practical environmental applications (Senthil et al., 2016; Cechinel et al., 2023).

Conclusion. Cobalt spinel ferrite represents a multifunctional material with distinct physicochemical advantages, including variable redox states, high magnetic permeability, and remarkable electrochemical stability. In this study, CoFe_2O_4 nanoparticles were successfully synthesized by the sol–gel method and comprehensively characterized. X-ray diffraction confirmed the formation of a single-phase cobalt ferrite with a spinel crystal structure (ICSD 1533163, space group $\text{Fd}\bar{3}\text{m}$). Energy-dispersive X-ray spectroscopy revealed only cobalt, iron, and oxygen, confirming the high purity of the obtained material. The FTIR spectrum displayed characteristic absorption bands associated with tetrahedral and octahedral metal–oxygen bonds, further validating the spinel structure. The resulting composition can be described as $(\text{Fe}^{3+})_a(\text{Co}^{2+}\text{Fe}^{3+})_\beta\text{O}_4$, consistent with the expected cation distribution. Beyond confirming successful synthesis, the obtained results emphasize the technological relevance of CoFe_2O_4 nanoparticles. Their combination of high saturation magnetization, catalytic activity, and structural stability makes them particularly attractive for environmental applications, such as wastewater treatment, where their magnetic nature enables efficient separation and potential reuse. Moreover, the unique balance of magnetic and chemical properties highlights their suitability for use in sensors, energy storage, and catalytic processes. Overall, the sol–gel synthesis route provides a reliable pathway for producing high-purity cobalt ferrite nanoparticles with broad prospects in advanced industrial and environmental technologies.

References

- Al-Harbi F.F., Khan W., Al-Hazmi F., Sulieman A., Aldhafiri A.M., Kumar R. (2022) Structural, magnetic, and optical properties of sol–gel synthesized cobalt ferrite nanoparticles. *Materials Chemistry and Physics*, 282:125958. DOI: 10.1016/j.matchemphys.2022.125958 (in Eng.).
- Cai X., Zhang H., Shang Y., Liu J., Li W. (2020) Sol–gel synthesis of cobalt ferrite nanoparticles with controllable size and enhanced magnetic properties. *Ceramics International*, 46:11903–11911. DOI: 10.1016/j.ceramint.2020.01.225 (in Eng.).
- Carta D., Casula M.F., Floris P., Falqui A., Mountjoy G., Corrias A. (2009) Synthesis and microstructure of CoFe_2O_4 nanoparticles prepared by sol–gel autocombustion. *Journal of Materials Chemistry*, 19:7291–7298. DOI: 10.1039/B912422B (in Eng.).
- Cechinel M.A.P., da Silva T.H., Domingos R., et al. (2023) Magnetic ferrite-based nanomaterials for wastewater treatment: synthesis, applications and challenges. *Environmental Nanotechnology, Monitoring & Management*, 20:100774. DOI: 10.1016/j.enmm.2023.100774 (in Eng.).
- Chae K.P., Hong Y.K., Choi B.C., Kim C.O. (2004) Structural and magnetic properties of nanocrystalline cobalt ferrite thin films prepared by sol–gel method. *Journal of Magnetism and Magnetic Materials*, 271:109–115. DOI: 10.1016/j.jmmm.2003.09.018 (in Eng.).

Estrada L.F., Barrera E.V., Martínez A.I. (2017) Magnetic properties of cobalt ferrite nanoparticles synthesized by different chemical routes. *Journal of Magnetism and Magnetic Materials*, 427:168–175. DOI: 10.1016/j.jmmm.2016.12.056 (in Eng.).

Jeseentharani V., Ramesh R., Arumugam S., Sivasankar S., Kumar M. (2012) Effect of particle size on structural, magnetic and dielectric properties of cobalt ferrite nanoparticles. *Journal of Materials Science: Materials in Electronics*, 23:2024–2030. DOI: 10.1007/s10854-012-0661-4 (in Eng.).

Kandasamy G., Sudame A., Luthra T., Saini K., Maity D. (2018) Functionalized cobalt ferrite nanoparticles for magnetic hyperthermia and MRI applications. *Journal of Colloid and Interface Science*, 514:534–543. DOI: 10.1016/j.jcis.2017.12.012 (in Eng.).

Kiani M.N., Ahmad S., Mehmood R., et al. (2023) Structural, optical and magnetic analysis of CoFe₂O₄ nanoparticles: evidence from FTIR and XRD. *ACS Omega*, 8:11245–11254. DOI: 10.1021/acsomega.2c05226 (in Eng.).

Koseoglu Y., Baykal A., Gozukara E., Kavas H., Toprak M.S. (2008) Structural and magnetic properties of nanocrystalline cobalt ferrite synthesized by solution combustion method. *Journal of Nanoscience and Nanotechnology*, 8:5845–5850. DOI: 10.1166/jnn.2008.180 (in Eng.).

Manikandan A., Vijaya J.J., Sundararajan M., Kennedy L.J. (2018) Green synthesis, structural, optical and magnetic properties of cobalt ferrite nanoparticles. *Journal of Molecular Structure*, 1160:409–415. DOI: 10.1016/j.molstruc.2018.02.013 (in Eng.).

Nadeem M., Hussain S., Ali I., Ahmad A., Gul I.H. (2022) Tailoring the structural, optical and magnetic properties of cobalt ferrite nanoparticles via sol–gel route for environmental and energy applications. *Journal of Alloys and Compounds*, 895:162604. DOI: 10.1016/j.jallcom.2021.162604 (in Eng.).

Senthil T., Suganya M., Rajan M., Vasantharaja D. (2016) Enhanced photocatalytic activity of cobalt ferrite nanoparticles for wastewater treatment. *Journal of Environmental Chemical Engineering*, 4(3):3050–3056. DOI: 10.1016/j.jece.2016.05.012 (in Eng.).

Shannon R.D., Prewitt C.T. (1976) Effective ionic radii in oxides and fluorides. *Acta Crystallographica Section B*, 32:751–767. DOI: 10.1107/S0567740876003571 (in Eng.).

Spizzo F., Del Bianco L., Rinaldi F., et al. (2016) Infrared spectroscopic investigation of spinel ferrites. *Journal of Alloys and Compounds*, 678:620–628. DOI: 10.1016/j.jallcom.2016.04.013 (in Eng.).

Spizzo F., Sgarbossa P., Sieni E., et al. (2016) Structural and magnetic properties of CoFe₂O₄ nanoparticles prepared by hydrothermal route. *Journal of Nanoparticle Research*, 18:126. DOI: 10.1007/s11051-016-3450-1 (in Eng.).

Sugurbekova G., Kairatkyzy S., Kudaibergenov S., Yeszhanov A., Seilkhanov T. (2024) Structural and magnetic properties of cobalt ferrite nanoparticles synthesized by sol–gel method. *Journal of Sol-Gel Science and Technology*, 110:117–126. DOI: 10.1007/s10971-023-06212-8 (in Eng.).

Thakur B.K., Kumar A., Singh J., et al. (2023) FTIR studies of nanoparticle surface hydration and organic residues. *Materials Chemistry and Physics*, 300:127450. DOI: 10.1016/j.matchemphys.2023.127450 (in Eng.).

Thakur P., Sharma A., Kumar S., Singh S., Chahal R.P., Verma N.K. (2023) Structural, magnetic and dielectric properties of CoFe₂O₄ nanoparticles synthesized by sol–gel route. *Ceramics International*, 49(6):9083–9093. DOI: 10.1016/j.ceramint.2022.11.226 (in Eng.).

Yin W., Hao S., Cao H. (2017) Solvothermal synthesis of magnetic CoFe₂O₄/rGO nanocomposites for highly efficient dye removal in wastewater. *RSC Advances*, 7:4062–4069. DOI: 10.1039/C6RA26948F (in Eng.).

Publication Ethics and Publication Malpractice in the journals of the Central Asian Academic Research Center LLP

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 journals of the Central Asian Academic Research Center LLP 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 Central Asian Academic Research Center LLP 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 Central Asian Academic Research Center LLP.

The Editorial Board of the Central Asian Academic Research Center LLP will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайтах:

www.nauka-nanrk.kz

<http://chemistry-technology.kz/index.php/en/arhiv>

ISSN 2518-1491 (Online), ISSN 2224-5286 (Print)

Ответственный редактор *А. Ботанқызы*

Редакторы: *Д.С. Аленов, Т. Апендиев*

Верстка на компьютере *Г.Д. Жадырановой*

Подписано в печать 23.12.2025.

Формат 60х88¹/₈. Бумага офсетная. Печать – ризограф.

13,5 п.л. Заказ 4.

«Central Asian Academic Research Center» LLP

Алматы, Қонаев к-сі, 142