

ISSN 2518-1483 (Online),
ISSN 2224-5227 (Print)

**ACADEMIC JOURNAL
OF PHYSICAL AND CHEMICAL SCIENCES**

**№2
2026**

ISSN 2518-1483 (Online),
ISSN 2224-5227 (Print)

2026 • 2



ACADEMIC JOURNAL OF PHYSICAL AND CHEMICAL SCIENCES

PUBLISHED SINCE JANUARY 1944

ALMATY, NAS RK

Editor-in-Chief:

ZHURINOV Murat Zhurinovich, Doctor of Chemical Sciences, Professor, Academician of IAAS and NAS RK, General Director of the Research Institute of Petroleum Refining and Petrochemicals (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=6602177960> <https://www.webofscience.com/wos/author/record/2017489>

Editorial Board:

KALIMOLDAYEV Maksat Nuradilovich, Doctor of Physical and Mathematical Sciences, Professor, Academician of NAS RK (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=56153126500>, <https://www.webofscience.com/wos/author/record/2428551>

ADEKENOV Sergazy Mynzhasarovich, Doctor of Chemical Sciences, Professor, Academician of NAS RK, Director of the JSC "Phytochemistry Research and Production Center", (Karaganda, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=7006153118>, <https://www.webofscience.com/wos/author/record/48648658>

RAMAZANOV Tlekkaul Sabitovich, (Deputy Editor-in-Chief), Doctor of Physical and Mathematical Sciences, Professor, Academician of NAS RK (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=6701328029>, <https://www.webofscience.com/wos/author/record/13503476>

ABIEV Rufat, Doctor of Technical Sciences (Biochemistry), Professor, Head of the Department of Optimization of Chemical and Biotechnological Equipment, St. Petersburg State Technological Institute (St. Petersburg, Russia), <https://www.scopus.com/authid/detail.uri?authorId=6602431781>, <https://www.webofscience.com/wos/author/record/1405661>

OLIVIERO Rossi Cesare, PhD (Chemistry), Professor at the University of Calabria (Calabria, Italy), <https://www.scopus.com/authid/detail.uri?authorId=57221375979>, <https://www.webofscience.com/wos/author/record/399768>

TIGINYANU Ion Mihailovich, Doctor of Physical and Mathematical Sciences, Academician, President of the Academy of Sciences of Moldova, Technical University of Moldova (Chisinau, Moldova), <https://www.scopus.com/authid/detail.uri?authorId=7006315935>, <https://www.webofscience.com/wos/author/record/524462>

SANG SU Kwak, PhD (Biochemistry, Agricultural Chemistry), Professor, Chief Scientist, Research Center for Plant Systems Engineering, Korea Research Institute of Bioscience and Biotechnology (KRIBB), (Daecheon, Korea), <https://www.scopus.com/authid/detail.uri?authorId=59286321700>, <https://www.webofscience.com/wos/author/record/30028581>

BERSIMBAYEV Rakhmetkazhi Iskenderovich, Doctor of Biological Sciences, Professor, Academician of NAS RK, L.N. Gumilyov Eurasian National University (Astana, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=7004012398>, <https://www.webofscience.com/wos/author/record/19854255>

CALANDRA Pietro, PhD (Physics), Professor, Institute for the Study of Nanostructured Materials (Rome, Italy), <https://www.scopus.com/authid/detail.uri?authorId=7004303066>, <https://www.webofscience.com/wos/author/record/616360>

BOSHKAEV Kuantai Avgazyevich, PhD, Associate Professor, Department of Theoretical and Nuclear Physics, Al-Farabi Kazakh National University (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=54883880400>, <https://www.webofscience.com/wos/author/record/2080231>

BURKITBAEV Mukhambetkali, Doctor of Chemical Sciences, Professor, Academician of NAS RK, (Almaty, Kazakhstan) <https://www.scopus.com/authid/detail.uri?authorId=8513885600>, <https://www.webofscience.com/wos/author/record/29017135>

QUEVEDO Hernando, Professor, National Autonomous University of Mexico (UNAM), Institute of Nuclear Sciences (Mexico City, Mexico), <https://www.scopus.com/authid/detail.uri?authorId=55989741100>, <https://www.webofscience.com/wos/author/record/30353742>

ZHUSUPOV Marat Abzhanovich, Doctor of Physical and Mathematical Sciences, Professor of the Department of Theoretical and Nuclear Physics, Al-Farabi Kazakh National University (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=6602166928>, <https://www.webofscience.com/wos/author/record/566>

KOVALEV Alexander Mikhailovich, Doctor of Physical and Mathematical Sciences, Academician of NAS of Ukraine, Institute of Applied Mathematics and Mechanics (Donetsk, Ukraine), <https://www.scopus.com/authid/detail.uri?authorId=7202799321>, <https://www.webofscience.com/wos/author/record/65533963>

TAKIBAEV Nurgali Zhabagaevich, Doctor of Physical and Mathematical Sciences, Professor, Academician of NAS RK, Al-Farabi Kazakh National University (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=24077239000>, <https://www.webofscience.com/wos/author/record/1671760>

KHARIN Stanislav Nikolaevich, Doctor of Physical and Mathematical Sciences, Professor, Academician of NAS RK, Kazakh-British Technical University (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=6701353063>, <https://www.webofscience.com/wos/author/record/2023295>

ABISHEV Medeu Erzhanovich, Doctor of Physical and Mathematical Sciences, Professor, Corresponding Member of NAS RK, (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=26530759900>, <https://www.webofscience.com/wos/author/record/1556025>

ABILMAGZHANOV Arlan Zainutallaevich, PhD in Chemistry, First Deputy Director General of JSC "Institute of Fuel, Catalysis and Electrochemistry named after D.V. Sokolsky", (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=57197468109>, <https://www.webofscience.com/wos/author/record/2024265>

ACADEMIC JOURNAL OF PHYSICAL AND CHEMICAL SCIENCES.

ISSN 2518-1483 (Online), ISSN 2224-5227 (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 № **KZ93VPY00121157** issued **05.06.2025**

Thematic scope: *physics and chemistry*.

Periodicity: 4 times a year.

<http://reports-science.kz/index.php/en/archive>

Бас редактор:

ЖҰРЫНОВ Мұрат Жұрыңұлы, химия ғылымдарының докторы, профессор, ХҒАҚ және ҚР ҰҒА академигі, Мұнай өңдеу және мұнай-химиясы ғылыми-зерттеу институтының бас директоры (Алматы, Қазақстан), <https://www.scopus.com/authid/detail.uri?authorId=6602177960%3A>; <https://www.webofscience.com/wos/author/record/2017489>

Редакция ұжымы:

КАЛИМОЛДАЕВ Максат Нұрәділұлы, физика-математика ғылымдарының докторы, профессор, ҚР ҰҒА академигі (Алматы, Қазақстан), <https://www.scopus.com/authid/detail.uri?authorId=56153126500>, <https://www.webofscience.com/wos/author/record/2428551>

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

РАМАЗАНОВ Тілеккабыл Сәбитұлы, физика-математика ғылымдарының докторы, профессор, ҚР ҰҒА академигі, (Алматы, Қазақстан), <https://www.scopus.com/authid/detail.uri?authorId=6701328029>, <https://www.webofscience.com/wos/author/record/13503476>

ӘБИЕВ Руфат, техника ғылымдарының докторы (биохимия), профессор, Санкт-Петербург мемлекеттік технологиялық институты «Химиялық және биотехнологиялық аппаратураны оңтайландыру» кафедрасының меңгерушісі, (Санкт-Петербург, Ресей), <https://www.scopus.com/authid/detail.uri?authorId=6602431781>, <https://www.webofscience.com/wos/author/record/1405661>

ОЛИВЬЕРО Росси Сесаре, PhD (химия), Калабрия университетінің профессоры (Калабрия, Италия), <https://www.scopus.com/authid/detail.uri?authorId=57221375979>, <https://www.webofscience.com/wos/author/record/399768>

ТИГІНЯНУ Ион Михайлович, физика-математика ғылымдарының докторы, академик, Молдова Ғылым Академиясының президенті, Молдова техникалық университеті (Кишинев, Молдова), <https://www.scopus.com/authid/detail.uri?authorId=7006315935>, <https://www.webofscience.com/wos/author/record/524462>

САНГ-СУ Квак, PhD (биохимия, агрохимия), профессор, Корея Биология және биотехнология ғылыми-зерттеу институты (KRIIBV), өсімдіктердің инженерлік жүйелері ғылыми-зерттеу орталығының бас ғылыми қызметкері, (Дэчон, Корея), <https://www.scopus.com/authid/detail.uri?authorId=59286321700>, <https://www.webofscience.com/wos/author/record/30028581>

БЕРСІМБАЕВ Рахметқажы Ескендірұлы, биология ғылымдарының докторы, профессор, ҚР ҰҒА академигі, Л.Н. Гумилев атындағы Еуразия ұлттық университеті. (Астана, Қазақстан), <https://www.scopus.com/authid/detail.uri?authorId=7004012398>, <https://www.webofscience.com/wos/author/record/19854255>

КАЛАНДРА Пьетро, PhD (физика), нанотехнология материалдары зерттеу институтының профессоры (Рим, Италия), <https://www.scopus.com/authid/detail.uri?authorId=7004303066>, <https://www.webofscience.com/wos/author/record/616360>

БОШКАЕВ Қуантай Авғазыұлы, Ph.D. Теориялық және ядролық физика кафедрасының доценті, әл-Фараби атындағы Қазақ ұлттық университеті (Алматы, Қазақстан), <https://www.scopus.com/authid/detail.uri?authorId=54883880400>, <https://www.webofscience.com/wos/author/record/2080231>

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/29017135>

QUEVEDO Hernando, профессор, Мексика ұлттық автономиялық университеті (UNAM), Ядролық ғылымдар институты (Мехико, Мексика), <https://www.scopus.com/authid/detail.uri?authorId=55989741100>, <https://www.webofscience.com/wos/author/record/30353742>

ЖҮСІПОВ Марат Абжанұлы, физика-математика ғылымдарының докторы, теориялық және ядролық физика кафедрасының профессоры, Әл-Фараби атындағы Қазақ ұлттық университеті (Алматы, Қазақстан), <https://www.scopus.com/authid/detail.uri?authorId=6602166928>, <https://www.webofscience.com/wos/author/record/566>

КОВАЛЕВ Александр Михайлович, физика-математика ғылымдарының докторы, Украина ҰҒА академигі, Қолданбалы математика және механика институты (Донецк, Украина), <https://www.scopus.com/authid/detail.uri?authorId=7202799321>, <https://www.webofscience.com/wos/author/record/65533963>

ТАКИБАЕВ Нұрғали Жабағұлы, физика-математика ғылымдарының докторы, профессор, ҚР ҰҒА академигі, Әл-Фараби атындағы Қазақ ұлттық университеті (Алматы, Қазақстан), <https://www.scopus.com/authid/detail.uri?authorId=24077239000>, <https://www.webofscience.com/wos/author/record/1671760>

ХАРИН Станислав Николаевич, физика-математика ғылымдарының докторы, профессор, ҚР ҰҒА академигі, (Алматы, Қазақстан), <https://www.scopus.com/authid/detail.uri?authorId=6701353063>, <https://www.webofscience.com/wos/author/record/2023295>

ӘБІШЕВ Медеу Ержанұлы, физика-математика ғылымдарының докторы, профессор, ҚР ҰҒА академигі, (Алматы, Қазақстан), <https://www.scopus.com/authid/detail.uri?authorId=26530759900>, <https://www.webofscience.com/wos/author/record/1556025>

ӘБІЛМАҒЖАНОВ Арлан Зайнуталлайұлы, химия ғылымдарының кандидаты, Д.В. Сокольский атындағы "Отын, катализ және электрохимия институты" АҚ Бас директорының бірінші орынбасары, (Алматы, Қазақстан), <https://www.scopus.com/authid/detail.uri?authorId=57197468109>, <https://www.webofscience.com/wos/author/record/2024265>

ACADEMIC JOURNAL OF PHYSICAL AND CHEMICAL SCIENCES

ISSN 2518-1483 (Online), ISSN 2224-5227 (Print)

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

Ақпарат агенттігінің мерзімді баспасөз басылымын, ақпарат агенттігін және желілік басылымды қайта есепке қою туралы ҚР Мәдениет және Ақпарат министрлігі «Ақпарат комитеті» Республикалық мемлекеттік мекемесі **05.06.2025 ж.** берген № **KZ93VPY00121157** Куәлік.

Тақырыптық бағыты: *физика, химия.*

Мерзімділігі: жылына 4 рет.

<http://reports-science.kz/index.php/en/archive>

Главный редактор:

ЖУРИНОВ Мурат Журинович, доктор химических наук, профессор, академик МАН и НАН РК, Генеральный директор НИИ нефтепереработки и нефтехимии (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=6602177960%3Cp%3Ehttps://www.webofscience.com/wos/author/record/2017489>

Редакционная коллегия:

КАЛИМОЛДАЕВ Максат Нурадилович, доктор физико-математических наук, профессор, академик НАН РК (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=56153126500>, <https://www.webofscience.com/wos/author/record/2428551>

АДЕКЕНОВ Сергезы Мынжасарович, доктор химических наук, профессор, академик НАН РК, директор АО "Научно-производственного центра "Фитохимия" (Караганда, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=7006153118>, <https://www.webofscience.com/wos/author/record/48648658>

РАМАЗАНОВ Тлеккабул Сабитович, (заместитель главного редактора), доктор физико-математических наук, профессор, академик НАН РК (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=6701328029>, <https://www.webofscience.com/wos/author/record/13503476>

АБИЕВ Руфат, доктор технических наук (биохимия), профессор, заведующий кафедрой «Оптимизация химической и биотехнологической аппаратуры», Санкт-Петербургский государственный технологический институт (Санкт-Петербург, Россия), <https://www.scopus.com/authid/detail.uri?authorId=6602431781>, <https://www.webofscience.com/wos/author/record/1405661>

ОЛИВЬЕРО Росси Чезаре, доктор философии (PhD, химия), профессор Университета Калабрии (Калабрия, Италия), <https://www.scopus.com/authid/detail.uri?authorId=57221375979>, <https://www.webofscience.com/wos/author/record/399768>

ТИГИНЯНУ Ион Михайлович, доктор физико-математических наук, академик, президент Академии наук Молдовы, Технический университет Молдовы (Кишинев, Молдова), <https://www.scopus.com/authid/detail.uri?authorId=7006315935>, <https://www.webofscience.com/wos/author/record/524462>

САНГ-СУ Квак, доктор философии (PhD, биохимия, агрохимия), профессор, главный научный сотрудник, Научно-исследовательский центр инженерных систем растений, Корейский научно-исследовательский институт бионауки и биотехнологии (KRIBB), (Дэжон, Корея), <https://www.scopus.com/authid/detail.uri?authorId=59286321700>, <https://www.webofscience.com/wos/author/record/30028581>

БЕРСИМБАЕВ Рахметкажи Искендинович, доктор биологических наук, профессор, академик НАН РК, Евразийский национальный университет им. Л.Н. Гумилева (Астана, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=7004012398>, <https://www.webofscience.com/wos/author/record/19854255>

КАЛАНДРА Пьетро, доктор философии (PhD, физика), профессор Института по изучению наноструктурированных материалов (Рим, Италия), <https://www.scopus.com/authid/detail.uri?authorId=7004303066>, <https://www.webofscience.com/wos/author/record/616360>

БОШКАЕВ Куантай Авгазыевич, PhD, преподаватель, доцент кафедры теоретической и ядерной физики, Казахский национальный университет им. Аль-Фараби (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=54883880400>, <https://www.webofscience.com/wos/author/record/2080231>

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/29017135>

QUEVEDO Hernando, профессор, Национальный автономный университет Мексики (UNAM), Институт ядерных наук (Мехико, Мексика), <https://www.scopus.com/authid/detail.uri?authorId=55989741100>, <https://www.webofscience.com/wos/author/record/30353742>

ЖУСУПОВ Марат Абжанович, доктор физико-математических наук, профессор кафедры теоретической и ядерной физики, Казахский национальный университет им. аль-Фараби (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=6602166928>, <https://www.webofscience.com/wos/author/record/566>

КОВАЛЕВ Александр Михайлович, доктор физико-математических наук, академик НАН Украины, Институт прикладной математики и механики (Донецк, Украина), <https://www.scopus.com/authid/detail.uri?authorId=7202799321>, <https://www.webofscience.com/wos/author/record/65533963>

ТАКИБАЕВ Нурғали Жабағәевич, доктор физико-математических наук, профессор, академик НАН РК, Казахский национальный университет им. Аль-Фараби (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=24077239000>, <https://www.webofscience.com/wos/author/record/1671760>

ХАРИН Станислав Николаевич, доктор физико-математических наук, профессор, академик НАН РК (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=6701353063>, <https://www.webofscience.com/wos/author/record/2023295>

АБИШЕВ Медеу Ержанович, доктор физико-математических наук, профессор, академик НАН РК, (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=26530759900>, <https://www.webofscience.com/wos/author/record/1556025>

АБИЛМАТЖАНОВ Арлан Зайнуталлаевич, кандидат химических наук, первый заместитель генерального директора АО «Институт топлива, катализа и электрохимии им. Д.В. Сокольского», (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=57197468109>, <https://www.webofscience.com/wos/author/record/2024265>

ACADEMIC JOURNAL OF PHYSICAL AND CHEMICAL SCIENCES

ISSN 2518-1483 (Online), ISSN 2224-5227 (Print)

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

Свидетельство № KZ93VPY00121157 о повторной регистрации периодического печатного издания информационного агентства, информационного агентства и сетевого издания, выданное Республиканским государственным учреждением «Комитет информации» Министерства культуры и информации Республики Казахстан 05.06.2025

Тематическая направленность: физика, химия.

Периодичность: 4 раза в год.

<http://reports-science.kz/index.php/en/archive>

© ТОО «Центрально-азиатский академический научный центр», 2026

CONTENTS

PHYSICS

Koshtybayev T.B., Aliev Sh., Aliyeva M.E., Zhavliyeva A.T. Covariant approach to the kinetic theory of plasma in a strong electromagnetic field.....	13
Kemelbekova A., Shongalova A., Bondar E., Otunchi Ye. Recycling technologies for spent lithium-ion batteries: environmental impact, recovered products, and future development trends.....	25
Koilyk N., Baimbetova G., Dalelkhankyzy A., Kaptagay G., Primkulova Zh. Simplification of the fermionic dynamical symmetry model for identical particles and its mapping into bosonic space.....	38
Massak B., Agyl-Mussapar O., Amangeldinova S., Kurmangaliyeva V., Snow M. Constraints on Yukawa-Type short-range interactions from neutron interferometry data.....	60
Nurbayev B.M., Dmitriyeva E.A. Tin-based perovskites.....	70
Nurtazina A.S., Zhubaev A.K. Study of the effect of highly dispersed ochre on the kinetic characteristics of epoxy composites.....	92
Shokanov A.K., Khamrayev Sh.I., Smikhan Y.A. Mössbauer studies of fly ash-based tracers.....	103
Ualikhanova U.A., Kurban Y.Y., Syzdykova A.M., Altayeva G.S., Altaibayeva A.B. Breaking the degeneracy between metric and teleparallel gravity theories through multi-messenger gravitational-wave astronomy.....	119
Zhadyranova A.A., Yerzhan B. Dynamics of bounce regimes in modified teleparallel gravity.....	134
Zhusupova N.K. Application of machine learning methods in the analysis of gravitational waves and cosmological models.....	151

CHEMISTRY

Aubakirov Ye., Akhmetova F., Tashmukhambetova Zh., Toshtay K., Amantaiuly K. Conversion of Polymer Waste into Synthetic Fuel via Modification of Taizhuzhen Zeolite with Tungsten Salts.....	164
Auyeshov A.P., Eskibayeva Ch.Z., Ibrayeva A.M., Alzhanov K.B., Dikanbayeva A.K. Physicochemical study of serpentinite waste and phosphoric acid products.....	175
Bayeshova A.K., Bayeshov A., Tuleshova E.Zh. Reduction of copper ions by zinc in the presence of titanium(iv) ions in sulfuric acid solutions.....	188

Fazylov S.D., Syzdykov A.K., Pustolaikina I.A., Kazhmuratova A.T., Tazhibay A.M. Production of α -, β -, γ -oligosaccharide clathrate cytosine complexes.....	200
Jalmakhanbetova R.I., Yelshibayeva A.M., Zhumagaliyeva Zh.Zh., Mukusheva G.K. Terpenoid compounds of <i>Artemisia terrae-albae</i> growing in the Turkestan Region of Kazakhstan.....	213
Kapizov O.S., Mukhanov D.K., Dzheldybaeva I.M., Seisenov E.B., Akimbayeva A.B. Sustainable recycling of ferrosilicon machining chips from metallurgical plants into high-performance silicon–carbon anodes.....	228
Massalimova B.K. Wastewater treatment methods for heavy metal removal: production of activated carbon from biomass.....	244
Nurtai Zh., Orynassar R., Aimaganbetova Z.K., Zhanturina N.N. Simulation of kinetic parameters of vinyl ester resin samples with diatomite and dimethyl methylphosphonate fillers.....	272
Sagyntayeva A., Zhanikulov N., Sudarev E., Kaiyrbaeva M., Zhakipbayev B. Research on the quality of raw materials for obtaining gypsum-cement-pozzolanic composite material.....	286
Satayeva S., Yermukhanova S., Urazova A., Mendygaliyeva A., Sabitov B. Obtaining benzene by photocatalytic oxidation of toluene.....	302
Sdikova G.Zh., Dalabayeva N.S., Sarova N.B., Muhtar T.Zh., Zhaltirbayeva N.K. Efficiency of phosphorus-containing inhibitors in protecting steel against corrosion.....	315
Shaimardan M., Azhikhanova Z., Abutalip M., Toktarbaiuly O. Isolation and Characterization of lignin from <i>Phlomis tuberosa</i> L. biomass via acid treatment.....	329
Yesimsiitova Z.B., Seisenova A., Oryngaliyeva S.Zh., Sanuar A., Manap K.R. Obtaining carbonized materials from rice husk using a mobile pyrolysis plant for energy applications.....	338
Zhetenova M.S., Suleimenova M.Sh., Nuraly A.M., Mutushev A.Zh., Kalimoldina L.M. Development and research of carotenoid-containing extracts obtained from plant raw materials.....	353
Zhortarova A.A., Kubicek V., Salkeyeva L.K., Ibrayev M.K., Seidakhmetova R.B. Synthesis and investigation of biological activity of 1,3-Bis(4-Phenylthiazol-2-yl)-2,4-Bis(N,N- Diethylamino)-1,3-Diaza-2,4-Diphosphétidine.....	367
Zhumabek M., Tungatarova S.A., Murzin D.Yu., Baizhumanova T.S. Structural and catalytic properties of SCS-derived Co–Al–Mg–Mn catalysts in dry reforming of methane.....	383

МАЗМҰНЫ

ФИЗИКА

Қоштыбаев Т.Б., Алиев Ш., Алиева Е.М., Жавлиева А.Т. Күшті электромагниттік өрістегі плазманың кинетикалық теориясына коварианттық көзқарас.....	13
Кемелбекова А., Шонғалова А., Бондарь Е., Отунчи Е. Пайдаланылған литий-ионды аккумуляторларды қайта өңдеу технологиялары: экологиялық әсері, алынатын өнімдер және болашақ даму бағыттары.....	25
Қойлық Н.О., Байымбетова Г.А., Дәлелханқызы А., Қаптағай Г.А., Примкулова Ж.Е. Бірдей бөлшектер үшін фермионды динамикалы-симметриялық модельді ықшамдау және оны бозондық кеңістікке бейнелеу.....	38
Масақ Б., Ағыл-Мұсапар О., Амангелдинова С., Курманғалиева В., Сноу М. Нейтрондық интерферометрия негізінде юкава типті қысқа-қашықтықтағы өзара әсерлесулерге шектеулер қою.....	60
Нұрбаев Б.М., Дмитриева Е.А. Қалайы негізіндегі перовскиттер.....	70
Нуртазина А.С., Жубаев А.К. Дисперстілігі жоғары охраның эпоксидті композиттердің кинетикалық сипаттамаларына ықпалын зерттеу.....	92
Шоканов А.К., Хамраев Ш.И., Смихан Е.А. Ұшқыш күл негізіндегі трассерлердің мессбауэрлік зерттеулері.....	103
Уалиханова У.А., Құрбан Е.Е., Сыздыкова А.М., Алтаева Г.С., Алтайбаева А.Б. Көп арналы гравитациялық-толқындық астрономия арқылы метрикалық және телепараллельді гравитация теорияларының айырмашылығын зерттеу.....	119
Жадыранова А.А., Ержан Б. Модификацияланған телепараллель гравитациядағы серпіліс режимдерінің динамикасы.....	134
Жусупова Н.К. Машиналық оқыту әдістерін гравитациялық толқындар мен космологиялық модельдерді талдауда қолдану.....	151

ХИМИЯ

Аубакиров Е., Ахметова Ф., Ташмұхамбетова Ж., Тоштай Қ., Амантайұлы Қ. Тайжүзген цеолитін вольфрам тұздарымен модификациялау арқылы полимер қалдықтарын синтетикалық отынға түрлендіру.....	164
Ауешов А.П., Ескибаева Ч.З., Ибраева А.М., Алжанов К.Б., Диканбаева А.К. Серпентинит қалдықтарының фосфор қышқылымен әрекеттесу өнімдерінің физика-химиялық зерттелуі.....	175

Башова А.К., Башов А.Б., Түлешова Э.Ж.

Мыс иондарын күкіртқышқылды ерітінділерде титан (IV) иондары қатысында мырышпен тотықсыздандыру.....188

Фазылов С.Д., Сыздықов А.Қ., Пустолайкина И.А., Қажмұратова А.Т., Тәжібай А.М.
Цитизиннің α -, β -, γ -олигосахаридтермен клатраттыкешендерін алу.....200

Джалмаханбетова Р.И., Елшібаева А.М., Жумагалиева Ж.Ж., Мукушева Г.К.
Қазақстанның Түркістан өңірінде өсетін *Artemisia terrae-albae* терпеноидты қосылыстары.....213

Капизов О.С., Муханов Д.К., Желдыбаева И.М., Сейсенов Е.Б., Акимбаева А.Б.
Металлургиялық зауыттардың ферросилиций жоңқаларын жоғары өнімді кремний-көміртекті анодтарға тұрақты қайта өңдеу.....228

Масалимова Б.К.
Ауыр металдардан ағын суларды жою әдістері: биомассада белсендендірілген көміртек алу.....244

Нуртай Ж., Орынбасар Р.О., Аймағанбетова З.К., Жантурина Н.Н.
Диатомит пен диметил метилфосфонат толтырғыштары бар винилэфир шайыр үлгілерінің кинетикалық параметрлерінің модельдеу.....272

Сағынтаева А., Жаниқұлов Н., Сударев Е., Қайырбаева М., Жакипбаев Б.
Гипс-цемент-пуццоланды композициялық материал алу үшін қажетті шикізаттардың сапасын зерттеу.....286

Сатаева С., Ермуханова С., Уразова А., Мендығалиева А., Сабитов Б.
Толуолдың фотокаталитикалық тотығуы арқылы бензол алу.....302

Сдикова Г.Ж., Далабаева Н.С., Сарова Н.Б., Мұхтар Т.Ж., Жалтырбаева Н.К.
Фосфор ингибиторлардың болаттың жемірілуіне қарсы тиімділігі.....315

Шаймардан М., Ажиханова Ж., Әбутәліп М., Тоқтарбайұлы О.
Phlomis Tuberosa L. өсімдігі биомассасынан лигнинді қышқылдық өңдеу арқылы бөліп алу және сипаттау.....329

Есимсиитова З.Б., Сейсенова А., Орынғалиева С.Ж., Сануар А., Манап К.Р.
Энергиялық қолдану үшін жылжымалы пиролиз қондырғысын пайдалану арқылы күріш қауызынан көміртекті материалдар алу.....338

Жетенова М.С., Сүлейменова М.Ш., Нұралы Ә.М., Мутушев А.Ж., Калимолдина Л.М.
Өсімдік шикізатынан алынған құрамында каротиноид бар сығындыларды әзірлеу және зерттеу.....353

Жортарова А.А., Kubicek V., Салькева Л.К., Ибраев М.К., Сейдахметова Р.Б.
1,3-бис(4-фенилтиазол-2-ил)-2,4-бис(N,N-диэтиламино)-1,3-диазо-2,4-дифосфетидиннің
синтезі және биологиялық белсенділігін зерттеу.....367

Жұмабек М., Тунгатарова С.А., Мурзин Д.Ю., Байжуманова Т.С.
SCS әдісімен дайындалған Co–Al–Mg–Mn катализаторларының метанның құрғақ
реформингіндегі құрылымдық және каталитикалық қасиеттері.....383

СОДЕРЖАНИЕ

ФИЗИКА

Коштыбаев Т.Б., Алиев Ш., Алиева М.Е., Жавлиева А.Т. Ковариантный подход к кинетической теории плазмы в сильном электромагнитном поле.....	13
Кемелбекова А., Шонгалова А., Бондарь Е., Отунчи Е. Технологии переработки отработанных литий-ионных аккумуляторов: экологическое воздействие, получаемые продукты и будущие направления развития.....	25
Қойлық Н.О., Баймбетова Г.А., Дәлелханқызы А., Қаптағай Г.Ә., Примкулова Ж.Е. Упрощение фермионной динамико-симметрической модели для идентичных частиц и её отображение в бозонное пространство.....	38
Масақ Б., Ағыл-Мұсапар О., Амангелдинова С., Курмангалиева В., Сноу М. Ограничения на юкавовские короткодействующие взаимодействия на основе нейтронной интерферометрии.....	60
Нурбаев Б.М., Дмитриева Е.А. Перовскиты на основе олова.....	70
Нуртазина А.С., Жубаев А.К. Исследование влияния высокодисперсной охры на кинетические характеристики эпоксидных композитов.....	92
Шоканов А.К., Хамраев Ш.И., Смихан Е.А. Мёссбауэровские исследования трассеров на основе летучей золы.....	103
Уалиханова У.А., Курбан Е.Е., Сыздыкова А.М., Алтаева Г.С., Алтайбаева А.Б. Разрешение вырождения метрических и телепараллельных теорий гравитации посредством многоканальной гравитационно-волновой астрономии.....	119
Жадыранова А.А., Ержан Б. Динамика отскоковых режимов в модифицированной телепараллельной гравитации.....	134
Жусупова Н.К. Применение методов машинного обучения при анализе гравитационных волн и космологических моделей.....	151

ХИМИЯ

Аубакиров Е., Ахметова Ф., Ташмухамбетова Ж., Тоштай К., Амантайулы К. Конверсия полимерных отходов в синтетическое топливо путем модификации цеолита тайжугзен солями вольфрама.....	164
--	-----

Ауешов А.П., Ескибаева Ч.З., Ибраева А.М., Алжанов К.Б., Диканбаева А.К. Физико-химическое исследование продуктов взаимодействия серпентинитовых отходов и фосфорной кислоты.....	175
Башова А.К., Башов А.Б., Тулешова Э.Ж. Восстановление ионов меди цинком в присутствии ионов титана (IV) в растворах серной кислоты.....	188
Фазылов С.Д., Сыздыков А.К., Пустолайкина И.А., Кажмуратова А.Т., Тажибай А.М. Получение α -, β -, γ -олигосахаридных клатратных комплексов цитизина.....	200
Джалмаханбетова Р.И., Елшыбаева А.М., Жумагалиева Ж.Ж., Мукушева Г.К. Терпеноидные соединения <i>Artemisia terrae-albae</i> , произрастающего в Туркестанском регионе Казахстана.....	213
Капизов О.С., Муханов Д.К., Желдыбаева И.М., Сейсенов Е.Б., Акимбаева А.Б. Устойчивая переработка стружки ферросилиция металлургических заводов в высокопроизводительные кремний-углеродные аноды.....	228
Масалимова Б.К. Методы очистки сточных вод от тяжелых металлов: получение активированного угля из биомассы.....	244
Нуртай Ж., Орынбасар Р.О., Аймаганбетова З.К., Жантурина Н.Н. Моделирование кинетических параметров образцов винилэфирных смол с наполнителями из диатомита и диметилметилфосфоната.....	272
Сагынтаева А., Жаникулов Н., Сударев Е., Кайырбаева М., Жакипбаев Б. Исследование качества сырья для получения гипсо-цементно-пуццоланового композиционного материала.....	286
Сатаева С., Ермуханова С., Уразова А., Мендыгилиева А., Сабитов Б. Получение бензола методом фотокаталитического окисления толуола.....	302
Сдикова Г.Ж., Далабаева Н.С., Сарова Н.Б., Мухтар Т.Ж., Жалтырбаева Н.К. Эффективность фосфорсодержащих ингибиторов против коррозии стали.....	315
Шаймардан М., Ажиханова Ж., Абуталип М., Токтарбай О. Выделение и характеристика лигнина из биомассы <i>Phlomis Tuberosa L.</i> с помощью кислотной обработки.....	329
Есимсиитова З.Б., Сейсенова А., Орынгалиева С.Ж., Сануар А., Манап К.Р. Получение карбонизированных материалов из рисовой шелухи с использованием мобильной пиролизной установки для энергетических применений.....	338

**Жетенова М.С., Сулейменова М.Ш., Нуралы А.М., Мутушев А.Ж.,
Калимолдина Л.М.**

Разработка и исследование каротиноидсодержащих экстрактов, полученных
из растительного сырья.....353

Жортарова А.А., Kubicek V., Салькева Л.К., Ибраев М.К., Сейдахметова Р.Б.

Синтез и исследование биологической активности 1,3-бис(4-фенилтиазол-2-ил)-2,4-
бис(N,N-диэтиламино)-1,3-дiazо-2,4-дифосфетидина.....353

Жумабек М., Тунгатарова С.А., Мурзин Д.Ю., Байжуманова Т.С.

Структурные и каталитические свойства Co–Al–Mg–Mn катализаторов, приготовленных
методом SCS, для сухого риформинга метана.....383

ACADEMIC JOURNAL
OF PHYSICAL AND CHEMICAL SCIENCES
ISSN 2224-5227
Volume 2.
Number 358 (2026), 272–285

<https://doi.org/10.32014/2026.2518-1483.451>

UDC: 536.6
IRSTI: 29.19.09

©Nurtai Zh.¹, Orynbassar R.², Aimaganbetova Z.K.², Zhanturina N.N.^{2*}, 2026.

¹K. Kulazhanov Kazakh Technology and Business University, Astana, Kazakhstan;

²K. Zhubanov Aktobe Regional University, Aktobe, Kazakhstan.

E-mail: nzhanturina@zhubanov.edu.kz

SIMULATION OF KINETIC PARAMETERS OF VINYL ESTER RESIN SAMPLES WITH DIATOMITE AND DIMETHYL METHYLPHOSPHONATE FILLERS

Nurtai Zhadyra — PhD, Associate Professor, K. Kulazhanov Kazakh Technology and Business University, Astana, Kazakhstan,

E-mail: zhadira_nurtai@mail.ru, <https://orcid.org/0000-0002-0744-0389>;

Orynbassar Raigul — Candidate of Technical Sciences, Associate Professor, K. Zhubanov Aktobe Regional University, Aktobe, Kazakhstan,

E-mail: raihan_06_79@mail.ru, <https://orcid.org/0000-0002-6198-3018>;

Aimaganbetova Zukhra — PhD, Associate Professor, Docent, K. Zhubanov Aktobe Regional University, Aktobe, Kazakhstan,

E-mail: zukhraaimaganbetova@mail.ru, <https://orcid.org/0000-0002-8765-516X>;

Zhanturina Nurgul — PhD, Associate Professor, Docent, K. Zhubanov Aktobe Regional University, Aktobe, Kazakhstan,

E-mail: nzhanturina@zhubanov.edu.kz, <https://orcid.org/0000-0001-9540-6334>.

Abstract. This article presents the results of predicting the kinetic properties of composite materials based on vinyl ester resin (VER) with the addition of diatomaceous earth and dimethyl methylphosphonate (DMMP) using the Netzsch Kinetics Neo software based on the results of thermogravimetric analysis (TGA). The VER samples were synthesized at the University of Science and Technology of China (Hefei, China) as part of a project funded under a targeted grant program. The kinetic characteristics of four samples were predicted based on the results of thermogravimetric analysis: Pure VER, VER + DE – a VER sample with a diatomite concentration of 25%, VER+DE/DMMP – VER with physically mixed DMMP and diatomite at concentrations of 12.5% and 12.5%, respectively, and VER + DE@DMMP – a sample with DMMP immobilized in the pores of diatomite (25%). Based on the TGA curves, models were selected in the Netzsch Kinetics Neo software, which allow for the prediction of the samples' kinetic properties under specific conditions over a defined period of time—something that is not feasible under laboratory conditions. Models were selected in the Netzsch Kinetics

Neo software. For the pure sample, the model corresponded to a simple first-order reaction; for VER with diatomite, independent reactions (simple and diffusion); for VER+DE/DMMP and VER+DE@DMMP, autocatalytic A2 and A3, and diffusion D3.

The results of the analysis showed that pure VER decomposes very slowly at low temperatures, but quite rapidly at high temperatures, compared to the other samples. The VER+DE/DMMP and VER+DE@DMMP samples exhibit a higher decomposition rate in the initial stages, whereas mass loss slows down at high temperatures.

In the dynamic mode, the pure VER sample showed the shortest decomposition time and the lowest temperature. In the immobilized sample, decomposition proceeds slightly faster than in the diatomite sample. The composite with physically mixed diatomite and DMMP demonstrated intermediate decomposition temperatures and times.

The results obtained open up opportunities for the development of new fire-resistant materials with controllable functional properties.

Keywords: vinyl ester resin, diatomite, DMMP, thermogravimetric analysis, Netzsch Kinetics Neo, degradation, decomposition time

Acknowledgments. This work was supported by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. BR28712729).

For citations: Nurtai Zh., Orynbassar R., Aimagambetova Z.K., Zhanturina N.N. Simulation of Kinetic Parameters of Vinyl Ester Resin Samples with Diatomite and Dimethyl Methylphosphonate Fillers. *Academic Journal of Physical and Chemical Sciences*. 2026. No.2. Pp. 272–285. DOI: <https://doi.org/10.32014/2026.2518-1483.451>

©Нуртай Ж.¹, Орынбасар Р.О.², Аймаганбетова З.К.²,
Жантурина Н.Н.^{2*}, 2026.

¹Қ. Құлажанов атындағы Қазақ технология және бизнес университеті,
Астана, Қазақстан;

²Қ. Жұбанов атындағы Ақтөбе өңірлік университеті, Ақтөбе, Қазақстан.
E-mail: nzhanurina@zhubanov.edu.kz

ДИАТОМИТ пен ДИМЕТИЛ МЕТИЛФОСФОНАТ ТОЛТЫРҒЫШТАРЫ БАР ВИНИЛЭФИР ШАЙЫР ҮЛГІЛЕРІНІҢ КИНЕТИКАЛЫҚ ПАРАМЕТРЛЕРІНІҢ МОДЕЛЬДЕУ

Нуртай Жадыра — PhD, қауымдастырылған профессор, Қ. Құлажанов атындағы Қазақ технология және бизнес университеті, Астана, Қазақстан,
E-mail: zhadira_nurtai@mail.ru, <https://orcid.org/0000-0002-0744-0389>;

Орынбасар Райгуль — техника ғылымдарының кандидаты, қауымдастырылған профессор, Қ. Жұбанов атындағы Ақтөбе өңірлік университеті, Ақтөбе, Қазақстан,
E-mail: raihan_06_79@mail.ru, <https://orcid.org/0000-0002-6198-3018>;

Аймаганбетова Зухра — PhD, қауымдастырылған профессор, Қ. Жұбанов атындағы Ақтөбе өңірлік университеті, Ақтөбе, Қазақстан,

E-mail: z.aimaganbetova@zhubanov.edu.kz, <https://orcid.org/0000-0002-8765-516X>;

Жантурина Нургул — PhD, қауымдастырылған профессор, Қ. Жұбанов атындағы Ақтөбе өңірлік университеті, Ақтөбе, Қазақстан,

E-mail: nzhanurina@zhubanov.edu.kz, <https://orcid.org/0000-0001-9540-6334>.

Аннотация. Бұл мақала Netzsch Kinetics Neo бағдарламасын пайдалана отырып, термогравиметриялық талдау (ТГА) нәтижелерінен негізінде диатомит пен диметил метилфосфонат (DMMP) қосылған винил эфир шайыры (VER) негізіндегі композиттік материалдардың кинетикалық қасиеттерін болжау зерттеуінің нәтижелерін ұсынады. VER үлгілері Қытай Ғылым және технология университетінде (Хэфэй, Қытай) мақсатты бағдарлама аясында қаржыландырылған жоба шеңберінде синтезделді. Термогравиметриялық талдау нәтижелері негізінде төрт үлгінің кинетикалық сипаттамаларын болжау жүргізілді: таза VER, VER + DE – диатомит концентрациясы 25% болатын VER үлгісі, VER+DE/DMMP – DMMP пен диатомит 12,5% және 12,5% концентрацияда физикалық араласқан VER; VER + DE@DMMP – диатомит тесіктерінде бекітілген DMMP-і бар үлгі (25%). ТГА қисықтарына сүйене отырып, Netzsch Kinetics Neo бағдарламасы арқылы модельдер таңдалды; бұл модельдер үлгілердің белгілі бір жағдайларда белгіленген уақыт аралығындағы кинетикалық қасиеттерін болжауға мүмкіндік береді, ал зертханалық жағдайларда мұны жүзеге асыру мүмкін емес. Модельдер Netzsch Kinetics Neo бағдарламасында таңдалды. Таза үлгі үшін модель қарапайым бірінші реттік реакцияға сәйкес келді; диатомит қосылған VER үшін – тәуелсіз реакциялар (қарапайым және диффузиялық); VER+DE/DMMP және VER+DE@DMMP үшін – автокаталитикалық А2 және А3, диффузиялық D3.

Талдау нәтижелері таза VER-дің төмен температурада өте баяу ыдырайтынын, ал жоғары температурада басқа үлгілерге қарағанда салыстырмалы түрде тез ыдырайтынын көрсетті. VER+DE/DMMP және VER+DE@DMMP үлгілері бастапқы кезеңдерде ыдырау жылдамдығы жоғары болса, жоғары температурада массаның жоғалуы бәсеңдеді.

Динамикалық режимде таза VER үлгісі ыдырау уақытының ең қысқа болуын және ең төменгі температураны көрсетті. Иммобилизацияланған үлгіде ыдырау диатомит қосылған үлгіге қарағанда сәл жылдам жүреді. Физикалық жолмен араластырылған диатомит пен DMMP қоспасы ыдыраудың орташа температурасы мен уақытын көрсетті.

Алынған нәтижелер басқарылатын функционалдық қасиеттері бар жаңа отқа төзімді материалдарды әзірлеуге мүмкіндік береді.

Түйін сөздер: винил эфир шайыры, диатомит, DMMP, термогравиметриялық талдау, Netzsch Kinetics Neo, деградация, ыдырау уақыты

©Нуртай Ж.¹, Орынбасар Р.О.², Аймаганбетова З.К.²,
Жантурина Н.Н.^{2 *}, 2026.

¹Казахский университет технологий и бизнеса имени К. Кулажанова;

²Актюбинский региональный университет имени К. Жубанова.

E-mail: nzhanturina@zhubanov.edu.kz

МОДЕЛИРОВАНИЕ КИНЕТИЧЕСКИХ ПАРАМЕТРОВ ОБРАЗЦОВ ВИНИЛЭФИРНЫХ СМОЛ С НАПОЛНИТЕЛЯМИ ИЗ ДИАТОМИТА И ДИМЕТИЛМЕТИЛФОСФОНАТА

Нуртай Жадыра — PhD, ассоциированный профессор, Казахский университет технологий и бизнеса имени К. Кулажанова, Астана, Казахстан,

E-mail: zhadira_nurtai@mail.ru, <https://orcid.org/0000-0002-0744-0389>;

Орынбасар Райгуль — кандидат технических наук, ассоциированный профессор, Актюбинский региональный университет имени К. Жубанова, Актюбе, Казахстан,

E-mail: raihan_06_79@mail.ru, <https://orcid.org/0000-0002-6198-3018>;

Аймаганбетова Зухра — PhD, ассоциированный профессор, Актюбинский региональный университет имени К.Жубанова, Актюбе, Казахстан,

E-mail: z.aimaganbetova@zhubanov.edu.kz, <https://orcid.org/0000-0002-8765-516X>;

Жантурина Нургул — PhD, ассоциированный профессор, Актюбинский региональный университет имени К.Жубанова, Актюбе, Казахстан,

E-mail: nzhanturina@zhubanov.edu.kz, <https://orcid.org/0000-0001-9540-6334>.

Аннотация. В статье представлены результаты прогнозирования кинетических характеристик композитных материалов на основе винилэфирной смолы (VER), модифицированной диатомитом и диметилметилфосфонатом (Dimethyl Methylphosphonate, DMMP), с использованием программного комплекса Netzsch Kinetics Neo на основе данных термогравиметрического анализа (ТГА). Образцы винилэфирной смолы были синтезированы в Университете науки и технологий Китая (г. Хэфэй, КНР) в рамках выполнения проекта программно-целевого финансирования. Проведено моделирование кинетических параметров четырех типов образцов: Pure VER (чистая винилэфирная смола), VER + DE (образец с содержанием диатомита 25 %), VER + DE/DMMP (образец с физически смешанными диатомитом и DMMP в концентрациях по 12,5 %), а также VER + DE@DMMP (образец с DMMP, иммобилизованным в порах диатомита, с общим содержанием наполнителя 25 %). На основании кривых ТГА в программе Netzsch Kinetics Neo были подобраны кинетические модели, позволяющие прогнозировать поведение материалов при различных температурных режимах и продолжительности воздействия, что затруднительно реализовать в лабораторных условиях. Для чистой смолы наиболее адекватной оказалась модель простой реакции первого порядка. Для образца VER + DE установлена комбинация независимых реакций первого порядка и диффузионного механизма. Для образцов VER + DE/DMMP и VER + DE@DMMP наиболее соответствующими оказались автокаталитические модели A2 и A3 в сочетании с диффузионной моделью D3. Результаты показали, что чистая винилэфирная смола характеризуется медленным разложением при низких температурах.

турах и более интенсивной деградацией при высоких температурах по сравнению с модифицированными образцами. Композиты VER + DE/DMMP и VER + DE@DMMP демонстрируют повышенную скорость разложения на начальных стадиях процесса, тогда как при высоких температурах скорость потери массы снижается. В динамическом режиме чистая смола характеризуется минимальным временем термического разложения и наиболее низкой температурой деструкции. Для образца с иммобилизованным DMMP процесс разложения протекает несколько быстрее, чем для композита, содержащего только диатомит. Образец с физически смешанными диатомитом и DMMP характеризуется промежуточными значениями температуры и времени разложения. Полученные результаты свидетельствуют о перспективности использования диатомита и диметилметилфосфоната для создания новых огнестойких полимерных материалов с регулируемыми эксплуатационными свойствами.

Ключевые слова: винилэфирная смола, диатомит, DMMP, термогравиметрический анализ, Netzsch Kinetics Neo, деградация, время разложения

Introduction. Polymer composites are a special class of materials that combine a polymer matrix with reinforcing or functional fillers, enabling the production of materials with predetermined physical, chemical, mechanical, and performance properties. Due to their low weight, low cost, and desirable thermal properties, they are widely used in industries such as construction, transportation, aviation, energy, and the chemical industry (Wu et al., 2023).

A significant drawback is the rapid flammability and combustibility of the polymer matrix, as well as rapid heat release. To address this issue, the development of flame retardants that create a protective barrier during combustion and prevent the formation of carbon residue is becoming increasingly relevant (Wang et al., 2023).

Vinyl ester resins (VER) are unsaturated polyester resins with enhanced chemical resistance and strength (Pączkowski et al., 2022). These materials are produced by reacting epoxy resin with methacrylic acid. The resulting epoxyacrylates dissolve in monomers. The resulting liquid resins can be used similarly to unsaturated polyester resins (UPR) (Nodehi et al., 2022).

Vinyl ester resins can be viewed as a compromise between unsaturated polyester and epoxy resins (Todjiyev et al., 2026).

However, due to their polymer matrix, ECMs are not sufficiently fire-resistant, which limits their application (Hu et al., 2022). This problem has been partially solved by physically adding fire-retardant substances to the resins or chemically introducing fire-retardant groups into their network structure (Zhang et al., 2020). However, while flame retardants increase the material's fire resistance, they simultaneously contribute to the deterioration of certain physicochemical properties (Li et al., 2022).

One of the fillers that minimally degrades the properties of the polymer matrix of the fire-retardant material is dimethyl methylphosphonate (DMMP), which possesses flame-retardant properties through

the interaction of the generated radicals with $H\bullet$ and $OH\bullet$ radicals (Xavier et al.,

2025). Due to its volatility, DMMP does not remain in the polymer matrix for long, and its effect is short-lived.

Scientists from the University of Science and Technology of China have found a way to ensure the long-term flame-retardant properties of DMMP by immobilizing DMMP in the micro- and nanoporous channels of diatomaceous earth (DE) and then incorporating it into vinyl ester resin (VER) (Xie et al., 2026).

The choice of diatomite was justified, first, by its widespread occurrence in Kazakhstan (Aktobe Region), and second, by its porous structure, which stems from its origin in sedimentary rocks and algae (Xu et al., 2019). The fire-retardant and flame-suppressing properties of diatomite are well known (Bi et al., 2024).

When characterizing new materials using analytical methods to determine thermal properties, thermogravimetric analysis is employed, which allows for the determination of mass loss at various temperatures under a specified heating rate. In the Netzsch Kinetics Neo software, based on the analysis data, it is possible to determine predictive kinetic characteristics, such as the degree of degradation over a very long period of time that cannot be analyzed under laboratory conditions, the calculation of the degradation temperature, the degradation time at very high heating rates that cannot be set on a laboratory instrument, and other characteristics (Harter et al., 2022).

This study presents data on the prediction of kinetic characteristics of VER-based composites with diatomite and DMMP additives based on thermogravimetric analysis using the Netzsch Kinetics Neo software.

Materials and Methods. Composite materials based on vinyl ester resin with the addition of diatomaceous earth and DMMP were prepared at the University of Science and Technology of China (Hefei, China) as part of a project funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. BR28712729) [[16]].

Four VER samples were used to record and study the kinetic characteristics:

Pure VER, VER + DE – a VER sample with a diatomite concentration of 25%, VER+DE/DMMP – VER with physically mixed DMMP and diatomite at concentrations of 12.5% and 12.5%, respectively, VER + DE@DMMP – a sample with DMMP immobilized in the pores of diatomite (25%).

The composite containing DE@DMMP was prepared by first vacuum-immobilizing DMMP within the pores of DE (producing DE@DMMP), after which the resulting filler was incorporated into vinyl ester resin (VER) with stirring until a homogeneous dispersion was achieved. The mixture was degassed under vacuum, then a curing accelerator and initiator (each at 1.5 wt.% relative to the resin) were added, poured into molds, and cured at room temperature until the composite was fully formed.

Thermogravimetric analysis was performed on a NETZSCH TG 209 F1 Libra (Germany) instrument, dynamically heating the sample in a 40 mL/min flow of inert nitrogen gas from room temperature to 800 °C. The heating rate was 10 °C/min.

Kinetics analysis was performed using the NETZSCH Kinetics-Neo (Germany) software. The program works as follows: first, TGA data obtained under real-world conditions—that is, up to a temperature of 800 °C with a heating rate of 10 °C/min—are

loaded into the program. Then, based on the TGA data, the program selects a model corresponding to a single reaction or several parallel reactions. Using this program, it is possible to predict the thermal properties of a material under certain conditions that cannot be replicated in a laboratory, such as very high temperatures, high heating rates, isothermal conditions, and the behavior of the material over an unlimited period of time.

Results and Discussion. We obtained the thermogravimetric analysis results of the four samples and performed modeling in the NETZSCH KINETIC NEO program. The following figures show the models (Figures 1, 2, 3, and 4).

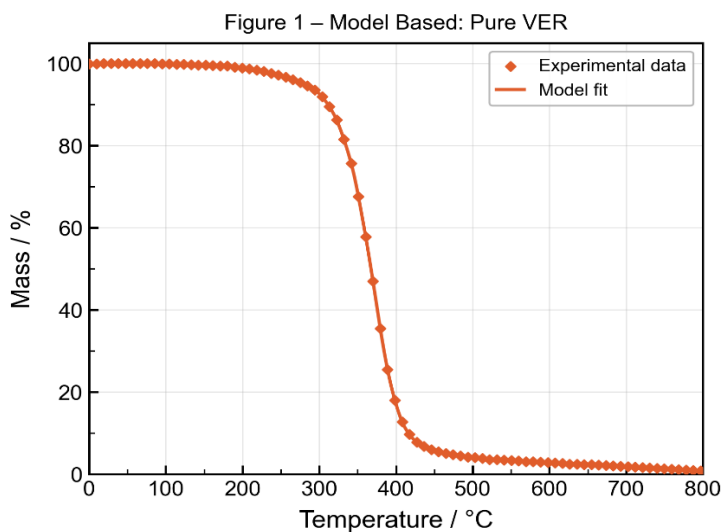


Figure 1. Model of pure VER.

The TGA curve shows that significant mass loss in the pure VER sample begins at 300 degrees, and by 400 degrees, half of the sample's mass has already been lost. From 440 degrees onward, the mass begins to decrease only slightly. Accordingly, degradation begins after 27 minutes, 50% of the mass is lost after 36 minutes, and the rate of loss slows down after 42 minutes. It takes about an hour for the mass to be completely lost.

The reaction model of the pure sample corresponds to a simple first-order F_n reaction, and the activation energy is 103.5 kJ/mol.

The reaction follows the following formula

$$da/dt = k \cdot (1-a)^1$$

here α conversion degree, k – rate constant.

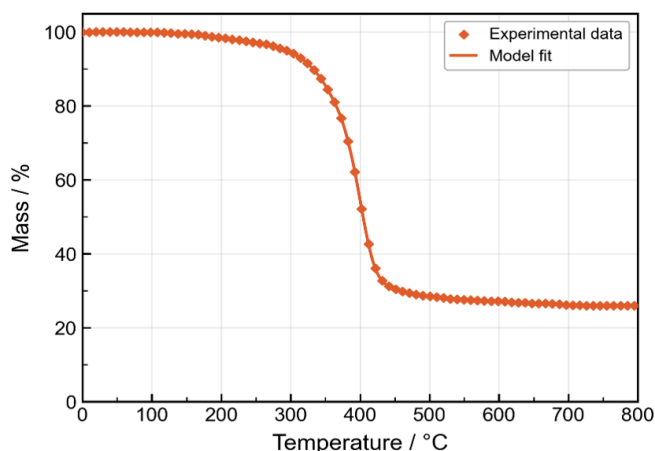


Figure 2. Model of VER + DE.

A significant loss of mass in the VER sample containing diatomite also begins at a temperature of 300 degrees, reaching 50% decomposition at 419 degrees. From 454 degrees onward, the mass begins to decrease slightly. At a temperature of 800 degrees, approximately 30% of the mass remains. Accordingly, degradation begins at 29 minutes, 50% of the mass is lost by 39 minutes, and the rate of loss slows down after 45 minutes. It takes 77 minutes for the mass to decrease by 30%.

The model for the diatomite-added sample consists of two independent reactions – a first-order F_n reaction and a D3 reaction (181 kJ/mol and 13 kJ/mol, respectively).

D3 — Diffusion model (3D: Jander model). This model describes diffusion-controlled processes in solid materials. The reaction equation is:

$$1 - \frac{2}{3} \alpha - (1 - \alpha)^{2/3} = kt$$

Here, the speed is highly dependent on the product being generated.

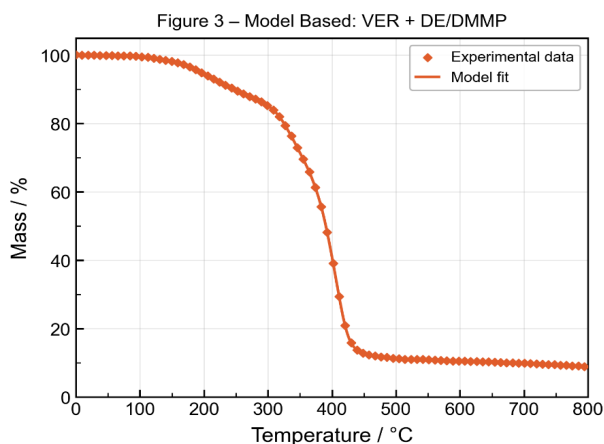


Figure 3. The model of VER+DE/DMMP.

A significant loss of mass in the VER sample, which contains physically mixed DMMP and diatomite, begins at a temperature of 303 degrees, reaching 50% decomposition at 408 degrees. From 458 degrees onward, the mass begins to decrease slightly. At a temperature of 800 degrees, approximately 20% of the mass remains. Accordingly, degradation begins at 28 minutes, 50% of the mass is lost by 38 minutes, and the rate of loss slows down after 43 minutes. It takes 77 minutes for the mass to decrease by 20%.

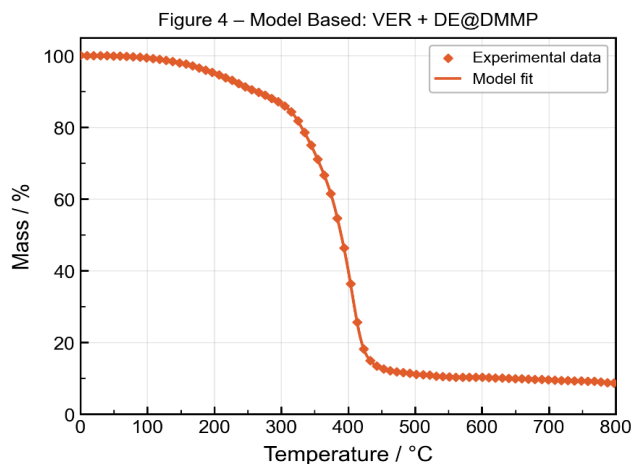


Figure 4. The model of VER + DE@DMMP.

A significant loss of mass in the VER sample, with DMMP mobilized in the diatomite pores, begins at a temperature of 313 degrees, reaching 50% decomposition at 405 degrees. From 453 degrees onward, the mass begins to decrease slightly. At a temperature of 800 degrees, approximately 15% of the mass remains. Accordingly, degradation begins at 29 minutes, 50% of the mass is lost by 38 minutes, and the rate of loss slows down after 43 minutes. It takes 75 minutes for the mass to decrease by 15%.

The VER+DE/DMMP and VER + DE@DMMP models correspond to three independent parallel reactions: A2 (21–48 kJ/mol), A3 (52–129 kJ/mol), D3 (164–40 kJ/mol). The activation energies for the VER+DE/DMMP and VER + DE@DMMP models are shown in parentheses.

A2 — Autocatalytic reaction model, corresponding to equation

$$d\alpha/dt = k \cdot \alpha \cdot (1 - \alpha).$$

According to the equation, the reaction starts slowly, then accelerates sharply, and finally slows down.

A3 — Autocatalytic reaction model

$$d\alpha/dt = k \cdot \alpha^2 \cdot (1 - \alpha),$$

here, the rate is highly dependent on the product being generated.

It can be observed here that in the VER sample containing physically mixed diatomite and DMMP, autocatalysis is initiated more readily compared to the immobilized sample, whereas diffusion, conversely, proceeds more slowly. In the sample with immobilized DMMP, there is a protective barrier, which slows down the chemical reactions.

After importing the TGA data into the NETZSCH Kinetics-Neo software, we predicted the kinetic characteristics of the samples under isothermal conditions. In doing so, we estimated the rate of mass loss for the samples at specific temperatures.

The results are shown in Table 1, which presents data on the time of mass loss at specific fractions and at different holding temperatures.

Table 1. Time of mass loss at different temperatures.

	Time of 10% mass lost		Time of 50% mass loss	
Pure VER	100 ⁰	17 month	100 ⁰	11 years
	200	90 hours	200	3 days
	300	1.5 hours	300	35 min
	400	18 min	400	2 min
VER+DE	100 ⁰	2.9 year	100 ⁰	23 years
	200	1 day	200	9 days
	300	12 min	300	3.6 hour
	400	0.7 min	400	6 min
VER+DE/DMMP	100 ⁰	3 days	100 ⁰	11 days
	200	1.8 hours	200	7 hours
	300	3 min	300	37 min
	400	36 sec	400	6.8 min
VER + DE@DMMP	100 ⁰	4.8 hour	100 ⁰	4.5 days
	200	29 min	200	4 hour
	300	5 min	300	33 min
	400	1.2 min	400	5.7 min

According to the program data, the maximum mass loss for pure VER is 82%, for the VER+DE sample it is 68%, for VER+DE/DMMP it is 79%, and for VER+DE@DMMP it is 84%.

The rate of mass loss depends heavily on temperature, and as the temperature rises, the degradation rate increases sharply.

VER+DE is the least thermally stable at low temperatures (2.9 years to 10% loss at 100°C—longer than Pure), but at high temperatures (300–400°C), degradation occurs more rapidly.

VER+DE/DMMP loses 10% of its mass very quickly at 300–400 °C (3 min and 36 sec). The thermal stability of VER+DE@DMMP is intermediate.

At 100 and 200 degrees, pure VER and VER with diatomaceous earth degrade over years, whereas VER+DE/DMMP and VER + DE@DMMP degrade over days and hours. However, at high temperatures, the difference in degradation time disappears (minutes and hours).

The degradation rate depends on temperature; the higher the temperature, the faster the rate. Effect of additives:

VER+DE/DMMP and VER + DE@DMMP samples show a higher decomposition rate in the initial stages, while at high temperatures, mass loss slows down (6–7 min to 80%).

Samples with DMMP/diatomite (3 and 5) show a faster initial rate of degradation but sometimes slow down mass loss at high temperatures.

Pure VER degrades slowly at low temperatures but rapidly at 300–400 °C. For example, at 400 °C, 50% of the mass of the pure sample is lost in 2 minutes, while for the sample with a physical mixture of diatomaceous earth and DMMP it takes 6.8 minutes, and for the sample with immobilized diatomaceous earth it takes 5.7 minutes.

The next step in predicting the kinetic characteristics was to estimate the temperature-time degradation profile of the samples under dynamic conditions. While we obtained the TGA results in the laboratory at a heating rate of 10°C/min, the software allows users to select any heating rate.

The simulation in the software using the dynamic mode was done, setting the heating rate to 120 K/min, which simulates the material's behavior under fire conditions (Lyon et al., 2000) (Fig. 5).

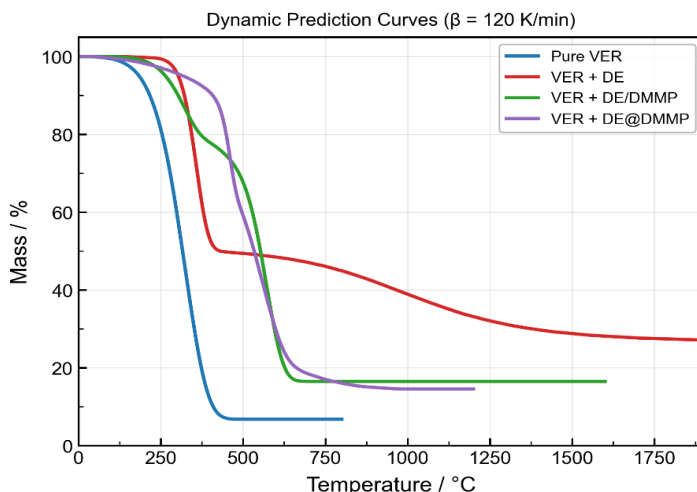


Figure 5. Dynamic prediction curves at a heating rate of 120 K/min.

The dynamic mode allows us to determine the time and temperature at which various degrees of material decomposition occur.

The graphs show that pure VER begins to decompose at 346 degrees, with diatomite at 370 degrees, and the sample with physically mixed DE and DMMP at a temperature slightly below 271 degrees. The immobilized sample showed the highest decomposition onset temperature—454 degrees.

At the same time, for all samples except the pure one, the decomposition is non-uniform; in the sample with diatomite, decomposition occurs very rapidly in the 400–500°C range and slows down significantly above 500°C. In the physically mixed sample, decomposition also proceeds in two stages at different rates, though the difference is not as significant. In the immobilized sample, the difference is almost negligible—

decomposition proceeds faster in the 200–400°C range and slightly slower from 400°C onward. It is likely that the interaction of DMMP with the diatomite surface provides partial stabilization of the system and slows down decomposition processes at elevated temperatures.

The half-decomposition temperatures for the samples are as follows: Pure VER—472 degrees, VER+DE—801, VER+DE/DMMP—600 degrees, VER+DE@DMMP—572 degrees. Here, the sample with diatomite showed the highest temperature. In the immobilized sample, however, the 50% decomposition temperature is still higher compared to the pure resin.

The temperatures at which the samples completely decompose are 560, 1500, 678, and 852 °C, respectively. Here, too, the sample containing diatomite exhibited the highest temperature, followed by the immobilized sample.

Time-dependent modeling showed that VER+ DE@DMMP begins to decompose after just 1.2 minutes, while the pure sample remains stable for a long time (2.5 min). The other two samples showed decomposition times intermediate between these two. Half of the mass remains in the pure sample after 3.8 minutes, in the diatomite sample after 6.2 minutes, in the physically mixed sample after 4.9 minutes, and in the immobilized sample after 4.6 minutes. Complete decomposition is significantly slower in the diatomite sample, taking 20 minutes, while the pure sample degrades completely in 4 minutes, VER+DE/DMMP in 5 minutes, and VER+DE@DMMP in 7.6 minutes.

If we analyze the comparative degradation temperatures of the samples under actual TGA experimental conditions at a rate of 10°C/min and according to the simulation at a rate of 120°C/min in the NETZSCH KINETIC NEO software, it can be observed that at 10°C/min, the temperature range from the onset of degradation to its slowdown varies from 300°C to 400°C, with times ranging from 29 min to 45 min. Complete degradation occurs approximately 70 minutes after the start of heating. Meanwhile, under conditions of 120°C/min, according to the simulation, the times of degradation onset vary significantly among samples in the range from 271°C to 454°C, and the slowing down occurs from 470°C to 720°C, which is significantly higher than at 10°C/min. The onset times of degradation at high heating rates range from 1 to 3 min, and complete degradation occurs within a wide range from 1 min to 20 min.

Conclusion. This article presents a simulation of the kinetic parameters of four VER-based composites with added diatomite and DMMP, based on TGA results: Pure VER, VER + DE – a VER sample with a 25% diatomite concentration, VER+DE/DMMP – VER with physically mixed DMMP and diatomite at concentrations of 12.5% and 12.5%, respectively, VER + DE@DMMP – a sample with DMMP immobilized in the pores of diatomite (25%).

To determine the kinetic parameters of the samples, the TGA results were exported to the NETZSCH Kinetics-Neo software, and models were constructed based on which predictions were made in isothermal and dynamic modes. The selected reactions are as follows: pure VER – a simple first-order F_n reaction; VER with diatomite – two independent reactions (F_n and D_3); VER+DE/DMMP and VER+DE@DMMP – A_2 , A_3 , D_3 .

A prediction was made of the degradation time of the composites in isothermal mode at temperatures ranging from 100 to 400 degrees.

According to the program data, the maximum mass loss for pure VER is 82%, for the VER+DE sample—68%, for VER+DE/DMMP—79%, and for VER+DE@DMMP—84%.

The rate of mass loss depends heavily on temperature: as temperature increases, the decomposition rate rises sharply.

The times required for 10%, 50%, and 80% mass loss of the samples were predicted. The analysis results showed that pure VER decomposes very slowly at low temperatures but relatively quickly at high temperatures compared to the other samples. The VER+DE/DMMP and VER+DE@DMMP samples exhibit a higher decomposition rate in the initial stages, whereas at high temperatures, mass loss slows down (6–7 minutes to 80%).

In the dynamic mode, the time and temperature at which various degrees of material decomposition are reached were predicted at a heating rate of 120 K/min, which corresponds to a simulated fire scenario.

The immobilized sample exhibited the highest decomposition onset temperature, while the sample with physically mixed diatomite and DMMP exhibited the lowest. For all samples except the pure one, the decomposition rate is non-uniform; for VER+DE@DMMP, the rate slows down as the temperature increases. The interaction of DMMP with diatomite leads to partial stabilization of the system and a slowing of decomposition as the temperature rises.

The VER+DE sample (801°C) decomposes the slowest, while half of the pure vinyl ester resin sample (472°C) degrades very quickly.

Complete decomposition of the diatomaceous earth sample occurs at a very high temperature.

Time-dependent modeling showed that decomposition occurs rapidly in the pure sample, most slowly in the diatomaceous earth sample, and slightly faster in the immobilized sample than in the diatomaceous earth sample. A dynamic comparison revealed an increase in the degradation temperature and a significant reduction in the degradation time at a rate of 120°C/min compared to the actual conditions of the TGA experiment.

Predictions of kinetic characteristics can be applied to the development of new polymer composites with functional properties that maintain stability under the influence of various factors, as well as fire-resistant structures that exhibit an extremely low degradation rate under fire conditions.

References

Bi Q.-Q., Li Y.-M., He L., Li Z., Wang D.-Y. (2024). Nanoporous flame retardants: Toward asphalt with enhanced fire safety and smoke suppression behavior. *Composites Communications*. – Vol. 47. – P. 101869. <https://doi.org/10.1016/j.coco.2024.101869> (in Eng.).

Harter A. G., Klapötke T. M., Lechner J. T., Stierstorfer J. (2022). Kinetic predictions concerning the long-term stability of TKX-50 and other common explosives using the NETZSCH Kinetics Neo software.



Propellants, Explosives, Pyrotechnics. – Vol. 47. – P. e202200031. <https://doi.org/10.1002/prep.202200031> (in Eng.).

Hu S.-L., Li Y.-M., Hu W.-J., Hobson J., Wang D.-Y. (2022). Strategic design unsaturated polyester resins composites with excellent flame retardancy and high tensile strength. *Polymer Degradation and Stability*. – Vol. 206. – P. 110190. <https://doi.org/10.1016/j.polymdegradstab.2022.110190> (in Eng.).

Li Z., Fu T., Lu J.-H., He J.-H., Li W.-D., Liu B.-W., Chen L., Wang Y.-Z. (2022). Ultra-high fire-safety unsaturated polyesters enabled by self-assembled micro/nano rod from Schiff base, diphenylphosphinyl group and nickel (II) metal. *Composites Part B: Engineering*. – Vol. 242. – P. 110032. <https://doi.org/10.1016/j.compositesb.2022.110032> (in Eng.).

Lyon R. E. (2000). Solid-state thermochemistry of flaming combustion. In: Grand A. F., Wilkie C. A. (Eds.), *Fire Retardancy of Polymeric Materials*. Marcel Dekker, New York. – P. 391-447. (in Eng.).

Nasiriddinovich Todjiyev J., Basimovich Parmanov A., Shokirjon o'g'li Tursunov S., Nurmanov E., Narmatillo Narzullayevich Mamatkulov N., Khudiyarova G. S., Sabidovna S., Abdurazmanova U., Yuldasheva U., Urozaliyevich Abdullaev J., Juraboev F. M. (2026). Vinyl esters of carboxylic acids: Synthesis, properties, applications, and technological processes. *Chemical Review and Letters*. – Vol. 9 (1). – P. 40–63. <https://www.chemrevlett.com> (in Eng.).

Nodehi M. (2022). Epoxy, polyester and vinyl ester-based polymer concrete: a review. *Innovative Infrastructure Solutions*. – Vol. 7. – P. 64. <https://doi.org/10.1007/s41062-021-00661-3> (in Eng.).

Paçzkowski P., Puszka A., Gawdzik B. (2022). Investigation of degradation of composites based on unsaturated polyester resin and vinyl ester resin. *Materials*. – Vol. 15 (4). – P. 1286. <https://doi.org/10.3390/ma15041286> (in Eng.).

Wang Z., Wu Z., Weng L., Ge S., Jiang D., Huang M., Mulvihill D. M., Chen Q., Guo Z., Jazzar A., He X., Zhang X., Xu B. B. (2023). A roadmap review of thermally conductive polymer composites: Critical factors, progress, and prospects. *Advanced Functional Materials*. – Vol. 33 (36). – P. 2301549. <https://doi.org/10.1002/adfm.202301549> (in Eng.).

Wu C., Xu F., Wang H., Liu H., Yan F., Ma C. (2023). Manufacturing technologies of polymer composites — a review. *Polymers*. – Vol. 15 (3). – P. 712. <https://doi.org/10.3390/polym15030712> (in Eng.).

Xavier J. R. (2025). Recent innovations in graphene-based nanocomposite coatings for enhanced flame retardancy in industrial applications. *Polymer Degradation and Stability*. – Vol. 240. – P. 111479. <https://doi.org/10.1016/j.polymdegradstab.2025.111479> (in Eng.).

Xie J., Akhmetova M., Zhanturina N., Hou Y., Bekeshev A., Hu W., Wang X., Hu Y., Chu F. (2026). Boosting the flame retardancy of vinyl ester resins via a DE@DMMP hybrid: Reducing migration and improving fire performance. *Polymer Degradation and Stability*. – Vol. 246. – P. 111963. <https://doi.org/10.1016/j.polymdegradstab.2026.111963> (in Eng.).

Xu W., Wang G., Xu J., Liu Y., Chen R., Yan H. (2019). Modification of diatomite with melamine coated zeolitic imidazolate framework-8 as an effective flame retardant to enhance flame retardancy and smoke suppression of rigid polyurethane foam. *Journal of Hazardous Materials*. – Vol. 379. – P. 120819. <https://doi.org/10.1016/j.jhazmat.2019.120819> (in Eng.).

Zhang X., Zhang W., Zeng G., Du J., Zhang W., Yang R. (2020). The effect of different smoke suppressants with APP for enhancing the flame retardancy and smoke suppression on vinyl ester resin. *Polymer Engineering and Science*. – Vol. 60 (2). – P. 314-322. <https://doi.org/10.1002/pen.25286> (in Eng.).

Publication Ethics and Publication Malpractice in the journals of the «Central Asian Academic Research Center» LLP (Almaty)

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 work described 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 originality detection service Cross Check <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.

Requirements for articles design for publication in the journal are available on the websites:

www.nauka-nanrk.kz

ISSN 2518-1483 (Online), ISSN 2224-5227 (Print)

<http://reports-science.kz/index.php/en/archive>

Managing Editor: T. Apendiev
Editors: D.S. Alenov, A. Shormakova
Computer layout: G.D. Zhadyranova

Signed for print: June 22, 2026
Format: 70×90 1/16. 24.5 printed sheets. Order No. 2.

*«Central Asian Academic Research Center» LLP
Almaty, Shevchenko Street, 28*