ISNN 3030-3907

2026
MAY
ISSUE - 5
VOLUME - 8

DEVELOPMENT OF SCIENCE

scientific journal



Development of science

Ilmiy jurnal

MAY 2026
Issue - 5, VOLUME – 8

ISSN 3030 -3907

Ilmiy jurnal OAK rayosatining 2024 yil 27 sentabrdagi 361-son qaroriga asosan 02.00.00 kimyo fanlari hamda 2025 yil 12 fevral 367- son qaroriga asosan 05.00.00 texnika fanlari bo‘yicha falsafa doktori (PhD) va fan doktori (DSc) ilmiy darajasiga talabgorlarning dissertatsiya ishlari yuzasidan dissertatsiyalari asosiy ilmiy natijalarini chop etish tavsiya etilgan milliy ilmiy nashrlar ro‘yxatiga kiritilgan.

BOSH MUHARRIR:
Temirov Alisher Hoshim o‘g‘li – texnika fanlari falsafa doktori (PhD),Dotsent.
TAHRIRIYAT KENGASH RAISI:
Fozilov Sadriddin Fayzullayevich – texnika fanlari doktori, professor
TAHRIRIYAT KENGASH A’ZOLARI

TEXNIKA FANLARI/ TECHNICAL SCIENCES/ ТЕХНИЧЕСКИЕ НАУКИ

Bozorov G‘ayrat Rashidovich
Buxoro Davlat Texnika Universiteti, professor
Abdurahmonov Olim Rustamovich
Buxoro Davlat Texnika Universiteti, professor
Adizov Bobur Zamirovich
O‘zbekiston Respublikasi Fanlar akademiyasi Umumiy va noorganik kimyo instituti, professor
Hayitov Ruslan Rustamjonovich
Buxoro Davlat Texnika Universiteti, professor
Jumayev Qayum Karimovich
Buxoro Davlat Texnika Universiteti, professor.
Berdiyev Dorob Murodovich
Islom Karimov nomidagi Toshkent Davlat Texnika Universiteti, professor
Maxmudov Rafiq Amonovich
Buxoro Davlat Texnika Universiteti, professor.
Tilloyev Lochin Ismatilloyevich
Buxoro Davlat Texnika Universiteti, dotsent.
Raxmonov Qahramon Sanakulovich
Buxoro Davlat Texnika Universiteti, dotsent.
Barakayev Nusratullo Rajabovich
Islom Karimov nomidagi Toshkent Davlat Texnika Universiteti, professor.
Jo‘rayev Xayrullo Fayziyevich
Buxoro Davlat Texnika Universiteti, professor.
Panoyev Erali Rajabboyevich
Buxoro Davlat Texnika Universiteti, dotsent.
Ataullayev Sherzod Nabiullyevich
Buxoro Davlat Texnika Universiteti, dotsent.
Murodov Malik Negmurodovich
Buxoro Davlat Texnika Universiteti, dotsent.
Axmedova Ozoda Bahronovna
Islom Karimov nomidagi Toshkent Davlat Texnika Universiteti.
Safarov Bahri Jumayevich
Buxoro Davlat Texnika Universiteti, dotsent.
Xaydarov Axtam Amonovich
Buxoro Davlat Texnika Universiteti, dotsent.
Safarov Jasur Alijon o‘g‘li
Buxoro Davlat Texnika Universiteti, dotsent.

KIMYO FANLARI/ CHEMICAL SCIENCES/ ХИМИЧЕСКИЕ НАУКИ

Axmedov Voxid Nizomovich
Buxoro Davlat Texnika Universiteti, professor
Umarov Baqo Bafoyevich
Buxoro Davlat Universiteti, professor
Kodirov Abduaxad Abduraximovich
Qarshi davlat Universiteti, professor
Qurbonov Mingniqul Jumagulovich
Qarshi davlat Universiteti, dotsent
Turemuratov Sharibay Naurizbaevich
O‘zbekiston Respublikasi Fanlar akademiyasi Qoraqalpog‘iston bo‘limi Bosh ilmiy kotibi, professor
Tursunov Kaxor Shonazarovich
Qarshi davlat Universiteti, professor
Do‘stov Hamro
Buxoro Davlat Texnika Universiteti, professor
Panoyev Nodir Shavkatovich
Buxoro Davlat Texnika Universiteti, dotsent.
Olimov Bobur Bahodir o‘g‘li
Buxoro Davlat Texnika Universiteti, dotsent.
Kasimov Sherzod Abduazimovich
Termiz Davlat Universiteti, professor.
Aliqulov Rustam Valiyevich
Termiz Davlat Universiteti, professor
Tropov Xamza Tursunovich
Samarqand Davlat Universiteti, professor

IQTISODIYOT FANLARI/ ECONOMICS/ ЭКОНОМИЧЕСКИЕ НАУКИ

Nizamov Aslitdin Badreddinovich
Buxoro Davlat Texnika Universiteti, professor.
Boboyev Akmal Choriyevich
Buxoro Davlat Texnika Universiteti, professor.
Ergashxojayeva Shaxnoza Djasurovna
Toshkent davlat iqtisodiyot universiteti, professor
Saidaxmedova Nodira Ilxomovna
Toshkent davlat iqtisodiyot universiteti, professor
Muxsinov Bekzod Toxirovich
Buxoro Davlat Texnika Universiteti, dotsent.
Shakarov Qulmat Ashirovich
Renessans ta'lim universiteti,dotsent.
Jumaeva Zulfiya Qayumovna
Buxoro Davlat Texnika Universiteti, dotsent.
Norova Salomat Yusupovna
Buxoro Davlat Texnika Universiteti, dotsent.
Avezova Shaxnoza Maxmudjonovna
Buxoro Davlat Texnika Universiteti, dotsent.
Jalilov Jamshid G‘anijonovich
Toshkent davlat iqtisodiyot universiteti, dotsent
Xasanova Gulruh Djumanazarovna
Buxoro Davlat Texnika Universiteti, dotsent.

PEDAGOGIKA FANLARI/ PEDAGOGICAL SCIENCES / ПЕДАГОГИЧЕСКИЕ НАУКИ

Siddiqova Sadoqat G‘afforovna
Buxoro Davlat Texnika Universiteti, dotsent.
Zoyirov Erkin Xalilovich
Buxoro Davlat Texnika Universiteti, DSc, professor
Gaffarov Feruz Hasanovich
Puchon Universiteti, *professor*
Ruziyev Davron Yuldashevich
Buxoro Davlat Universiteti, professor
Muradova Firuza Rashidovna
Buxoro Davlat Texnika Universiteti, professor.
Yunusova Gulandon Samiyevna
Buxoro Davlat Texnika Universiteti, professor.
To‘xtayeva Zebo Sharifovna
Buxoro Davlat Texnika Universiteti, professor.
Navro‘zova Gulchixra Nigmatovna
Buxoro Davlat Texnika Universiteti, dotsent.
Uzoqova Laylo Polvonovna
Buxoro muhandislik – texnologiya instituti, dotsent.
To‘raqulova Marjona Qiyom qizi
Buxoro Davlat Texnika Universiteti, dotsent.
Muradova Zarina Rashidovna
Buxoro Davlat Texnika Universiteti, dotsent.
Murodov Sanjar Aslonovich
Buxoro Davlat Texnika Universiteti, dotsent.
Shodiyev Jahongir Jo‘raqulovich
Buxoro Davlat Texnika Universiteti, dotsent
Gaffarov Laziz Hasanovich
Buxoro muhandislik – texnologiya instituti, dotsent.

Tahririyat a’zolarning to‘liq ro‘yxati jurnalning www.devos.uz saytida keltirilgan.

Tahririyat hay’ati a’zolarining tarkibini o‘zgartirish hamda qo‘shimcha kiritish yoki tahririyat a’zoligidan chiqarish bosh muharrir tomonidan amalga oshiriladi.

ISSN 3030-3907

Development of science ilmiy jurnali 2024 yil 15 aprel kuni №256445 sonli guvohnoma bilan Davlat ro‘yxatidan o‘tgan.

To‘plam elektron ko‘rinishda (pdf formatida) mualliflarga taqdim etiladi. To‘plamga kiritiladigan maqolalarning mazmuni, ulardagi statistik ma’lumotlar va me’yoriy hujjatlarning to‘g‘riligiga hamda har qanday fikr - mulohazalarga mualliflarning o‘zlari mas’ul hisoblanadilar. Talablarga javob bermaydigan maqolalar to‘plamga kiritilmaydi. Tashkiliy qo‘mita maqola matnini qisqartirish, qisman tuzatish kiritish, seksiyalarga joylashtirish huquqiga ega.

ISSN 3030-3907

ANALYTICAL REVIEW ON SYNTHESIS METHODS OF IMINES

Fotima Abduqaxxorova
PhD student, Faculty of Chemistry, National University of Uzbekistan named after Mirzo Ulugbek.
Tel: +998917701993
E-mail: ximfak.fm@mail.ru
Sunnatillo Salimov
Master's degree, Faculty of Chemistry, National University of Uzbekistan named after Mirzo Ulugbek.
Tel: +998917984818
E-mail: salimovsunnatillo0@gmail.com
Frunza Sapayev
Senior Lecturer, Department of Organic and Oil-Gas Chemistry, Faculty of Chemistry, National University of Uzbekistan named after Mirzo Ulugbek, PhD
Tursunali Kholikov
Professor, Department of Organic and Oil-Gas Chemistry, Faculty of Chemistry, National University of Uzbekistan named after Mirzo Ulugbek, Candidate of Chemical Sciences

Abstract. Imines are compounds that are an integral part of organic chemistry and contain an azomethine group (-C=N-). In the early years, Schiff bases were synthesized through condensation reactions of primary amines and aldehydes; today, synthesis methods based on green chemistry principles are also widely used. Schiff bases have been widely used in the pharmaceutical field due to their demonstrated antibacterial, antifungal, and antitumor biological activities. They are also of great interest as various ligands in coordination chemistry. In this article, recent research on Schiff bases was studied and comprehensively analyzed.

Keywords: schiff bases, azomethine, condensation, green chemistry, microwave, metal complex, biological activity, corrosion inhibitor.

Annotatsiya. Iminlar-tarkibida azometin guruhi (-C=N-) mavjud bo‘lgan va organik kimyoning ajralmas qismini tashkil etuvchi birikmalardir. Dastlabki davrlarda Shiff asoslari birlamchi aminlar va aldegidlarning kondensatlanish reaksiyalari yordamida sintez qilingan bo‘lsa, bugungi kunda yashil kimyo prinsiplariga asoslangan sintez usullaridan ham keng foydalanilmoqda. Shiff asoslari o‘zining yaqqol namoyon bo‘lgan antibakterial, antifungal (bakteriya va zamburug‘larga qarshi) va o‘smalarga qarshi (antitumor) biologik faolligi tufayli farmatsevtika sohasida keng qo‘llaniladi. Shuningdek, ular koordinatsion kimyoda turli xil ligandlar sifatida ham katta qiziqish uyg‘otmoqda. Ushbu

ISSN 3030-3907

maqolada Shiff asoslari bo‘yicha olib borilgan so‘nggi tadqiqotlar o‘rganildi va har tomonlama tahlil qilindi.

Kalit so‘zlar: shiff asoslari, azometin, kondensatlanish, yashil kimyo, mikroto‘lqin, metall kompleksi, biologik faollik, korroziya ingibitori.

Аннотация. Имины представляют собой соединения, содержащие азометиновую группу (-C=N-) и являющиеся неотъемлемой частью органической химии. В ранние периоды основания Шиффа синтезировали путем реакций конденсации первичных аминов и альдегидов; сегодня также широко применяются методы синтеза, основанные на принципах «зеленой» химии. Основания Шиффа находят широкое применение в фармацевтической сфере благодаря их выраженной антибактериальной, противогрибковой и противоопухолевой биологической активности. Они также представляют большой интерес в качестве различных лигандов в координационной химии. В данной статье были изучены и всесторонне проанализированы современные исследования, посвященные основаниям Шиффа.

Ключевые слова: Основания Шиффа, азометин, конденсация, зеленая химия, микроволны, металлический комплекс, биологическая активность, ингибитор коррозии.

INTRODUCTION.

Schiff bases are one of the most important representatives of modern organic chemistry due to their structural diversity and the possibility of modification with various functional groups. The composition of Schiff bases is characterized by a unique **imine (–C = N–)** functional group. These compounds are mainly formed by condensation of primary amines with aldehydes or ketones. Their ease of synthesis and high reaction yield are consistent with the principles of "green chemistry".

1. Historical Development Stages and Important Properties of Schiff Bases

Compounds known as Schiff bases or imines were first introduced to science **in 1864** by the German chemist ***Hugo Schiff***. [1] He discovered a new class of compounds by studying reactions between aniline and various aldehydes.The new class named after Schiff opened the way for extensive research in organic chemistry. In the early years, studies were conducted on simple aromatic compounds, as researchers focused their attention on studying the mechanism of imine group formation and describing its structure.

In 1889, ***Alfons Komb*** was among the first to establish that Schiff bases can form stable metal complexes with metals. He synthesized the complex of a Schiff base derived from ethylenediamine and acetylacetone with Copper(I) salts, thus

ISSN 3030-3907

laying the foundation for the synthesis of*metal complexes based on imines* in history [2]. In 1933, the German chemist ***Paul Pfeiffer*** announced *Salen-type* ligands, after which the main stage in the history of using Schiff bases as ligands began. Condensation of salicylaldehyde derivatives with diamine compounds yields imines with Salen-type structure having tetradentate (four donor centers) ligands. This imine, as shown in figure 1 demonstrates denticity through two imine groups (-C=N-) and phenol hydroxyl group [3]. Salen-type Schiff bases are widely used to form stable complexes with transition metals due to their structural symmetry and high coordination ability. These ligands also showed high efficiency in creating homogeneous catalysts due to their ability to stabilize metal ions at various oxidation states [4].

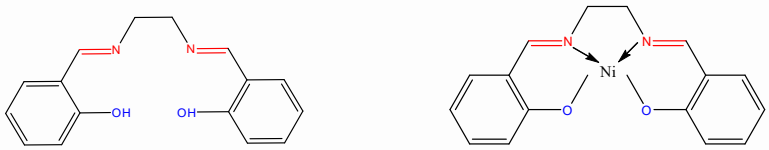


Figure 1. *Salen-type* ligand - N,N-bis(salicylidene)-orthoethylenediamine and its Nickel metall complex

In conclusion, Salen-type ligands serve as a basis for creating new functional systems in pharmaceutics, catalysis, and materials science due to their versatility.Schiff bases have made a great contribution to the development of coordination chemistry due to their important and unique structural properties.

The imine bond (-C=N-) exhibits unique properties such as stability and susceptibility to easy hydrolysis, characteristic of the reversibility of a covalent double bond. Taking these properties into account, Schiff base condensation is thermodynamically controlled; in this process, reactants re-bond through a "trial-and-error" mechanism until they reach the most stable thermodynamic state [5]. Reversible hydrolysis can be prevented by hydrogenating the imine bond under mild conditions. The reversibility of the C=N (imine) bond *self-assembly* process and enables the creation of remarkable structures such as stable rings, polynuclear complexes, and cages of various sizes.

Recent research has focused on identifying similarities between chemical design and visual art, and demonstrating how to create aesthetically pleasing structures. ***Fabbrizzi*** and his colleagues described in detail the synthesis of **Bistren cages** capable of accommodating and retaining anions and molecules within their cavities. Theyrevealed the concept of "beauty in chemistry" through the harmony of form and complex chemical mechanism [6]. Figure 2 shows a macrocyclic compound with complex structure created without metal ions — the Bistren cage.

ISSN 3030-3907

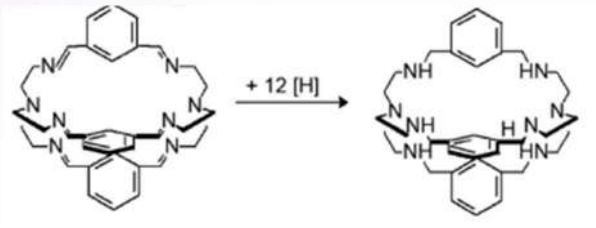
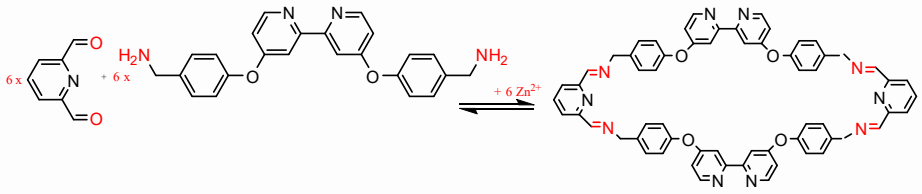


Figure 2. Bistren cage macrocyclic compound

This macrocyclic molecule perchlorate, bromide and other anions with in it'can accommodate, serving as baskets functioning.

When metal ions act as "templates", the shapes that can be synthesized become even more complex. For example,Borromean rings,, double helices, or tetrahedral cages — the geometric directing force of metal ions plays a decisive role in creating such complex structures. To create such complex structures,classical organic synthetic methods carried out through a sequence of irreversible, kinetically controlled steps yielded no results. The Scottish chemist ***Fraser Stoddart*** demonstrated that metal ionsserve as the main template for forming Borromean rings and opened an effective pathway to create complex structures [7,8]. **Borromean rings** are a complex structure consisting of three rings, all linked and inseparable, yet if any two are considered alone, they appear unconnected. Due to the tendency of the Zn(II) ion toward five-coordinate bonding, it forms the complex structure shown in figure 3 through the interlocking of three macrocycles.



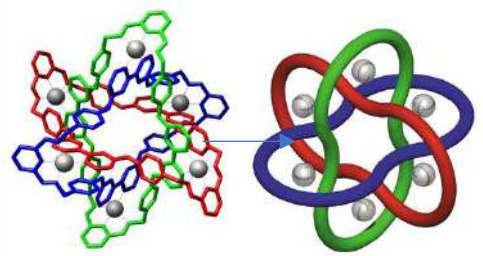


Figure 3. Borromean ring containing 6 Zn(II) ions

These processes occur due to the unique property of imines — their reversibility. Such syntheses involving metal ions are under thermodynamic control, forming the most suitable and stable complex shape for the metal ion geometry through a "trial-and-error" mechanism.

2. Synthesis of Schiff Bases by Traditional and "Green Chemistry" Principles.

ISSN 3030-3907

Schiff bases are synthesized by 2 methods: the first method is the traditional approach, where the reaction is carried out over a long period using various solvents and synthetic catalysts. The second method is based on "green chemistry" principles and includes microwave irradiation, ultrasound, and grinding methods.

Indian scientists studied the formation of imines in high yield from the condensation of low-electrophilic carbonyl compounds and weak nucleophilic amines [9]. They used *Lewis acids* to activate the carbonyl group in aldehydes, catalyze the nucleophilic attack of the amine, and dehydrate the system by removing water released at the final stage. In traditional methods for synthesizing Schiff bases, $ZnCl_2$, $TiCl_4$, $MgSO_4$-PPTS, $Ti(OR)_4$, H_2SO_4, $NaHCO_3$, $MgSO_4$, $Mg(ClO_4)_2$, H_3CCOOH, $Er(OTf)_3$, P_2O_5/Al_2O_3, HCl and similar acids have been used [10-13]. DMSO, DMF, dichloromethane, benzene, toluene, methanol, chloroform and others were used as solvents [9-12]. Figure 4 shows the general scheme for the synthesis of azomethine by the traditional method.

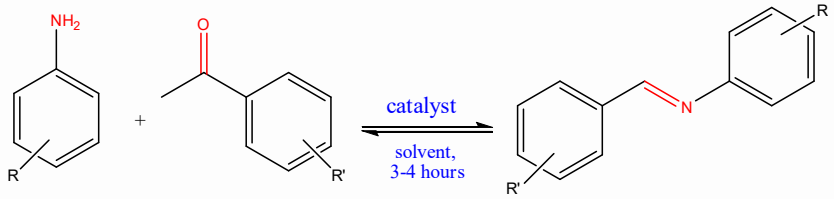


Figure 4. General scheme for obtaining imines by the traditional method

Indian researcher Venkatesh Rangaswamy and his colleagues carried out the condensation of 5-methoxysalicylaldehyde and 4-nitro-o-phenylenediamine using the traditional method. The condensation was carried out in absolute ethanol at 70°C for 6 hours with mechanical stirring. The antibacterial activity of the obtained Schiff base and its Ni^{2+}, Zr^{2+}, $Cd2^{+}$, metal complexes against Escherichia coli, Proteus mirabilis, Streptococcus pneumoniae, and Bacillus subtilisand other bacteria was studied [14]. Reaction equation is shown in Figure 5.

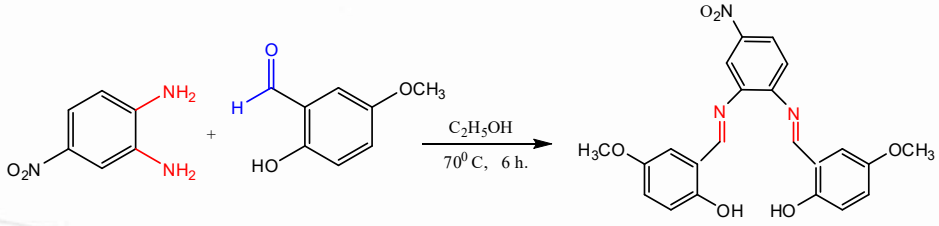


Figure 5. Synthesis of imin ligand via condensation of 4-nitro-o-phenylenediamine and 5-methoxysalicylaldehyde.

Traditional methods mainly use toxic and environmentally hazardous reagents and solvents [15]. In addition, they also have disadvantages such as high reaction temperature, long reaction duration,, excessive cost of dehydrating agents, and catalysts, sensitivity of catalysts, to moisture, and the requirement for

ISSN 3030-3907

special equipment. It has also been found that highly electrophilic carbonyl. compounds and strongly nucleophilic amines significantly reduce reaction efficiency.

Recent literature shows that researchers carrying out - the synthesis of organic molecules using microwave irradiation method based on green chemistry principles. Synthesis using microwave irradiation stands out from traditional. Synthesis methods for its economic and environmental convenience [16].

Indian researchers applied the microwave irradiation method using a natural acidic catalyst — cashew nut shell extract — – in the synthesis of Schiff bases. They conducted the reaction under solvent-free conditions, in a microwave oven at 600 W power, in a one-step method with in 80 to 120 seconds, 600 Vt. The reaction equation is shown in Figure 6 [17].

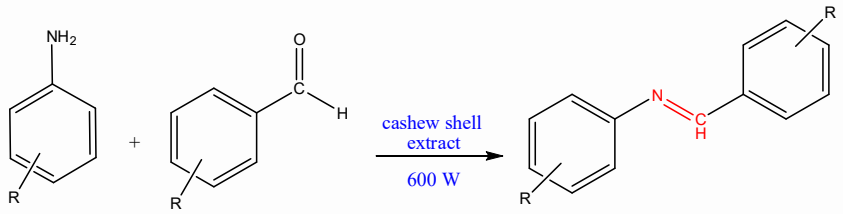


Figure 6. Synthesis of imin under microwave irradiation

As a result, the reaction product was obtained in high yield (from 80.00% to 88.27%).

In conclusion, the microwave method stands out from other methods for its short reaction time (from a few seconds to 10 minutes) and high yield (from 65% to 95%). This method is carried out without toxic solvents and is therefore safe for the environment. It sometimes enhances reactivity and selectivity that cannot be achieved in organic solvents, and has advantages such as reducing drying agents, energy, and time [18].Various environmentally clean acidic catalysts are often used in the microwave method. For example: cashew nut shell extract, glucose, acetic acid, grape juice, mango extract, and lemon juice have been used as natural catalysts [19,20].

Alixan and his students synthesized Schiff bases from aromatic aldehydes with 4,6-diamino-2-thiol pyrimidine molecule using lemon juice as a natural and environmentally clean catalyst. They noted that lemon juice (scheme 7) is a safe alternative catalyst replacing harmful and toxic solvents. This catalyst ensures the completion of the reaction in a short time and the product is obtained in high yield [21].

ISSN 3030-3907

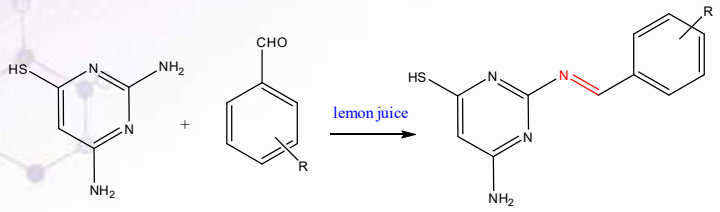


Figure 7. Synthesis of Schiff base using lemon juice

The ultrasonic method for synthesizing imines is considered much more convenient, efficient, and environmentally clean compared to traditional methods. Ultrasonic irradiation significantly accelerates many organic reactions, including imine synthesis. In experiments reported in the literature, imines were synthesized in just 10 minutes and high yields of 86% to 98% were achieved [22]. Based on green chemistry principles, synthesizing imines under UV irradiation compared to traditional methods has advantages such as waste reduction and energy savings. When synthesizing Schiff bases by the **ultrasonic method** active centers are formed in the initial reagents, helping the reaction proceed quickly even at low temperatures.

In imine synthesis, $SiO_2$was found to be the most effective catalyst, as it is widely available in nature, reusable, and superior in causing minimal environmental harm. The ultrasonic method does not lose its effectiveness not only in laboratory conditions but also in industrial-scale syntheses. In the reaction of benzaldehyde and p-methoxyaniline in ethanol under ultrasonic irradiation with silica catalyst, the product (N-benzylidene-4-methoxybenzylamine) was obtained in 99% yield, and it was found that the yield drops sharply without a catalyst [23].

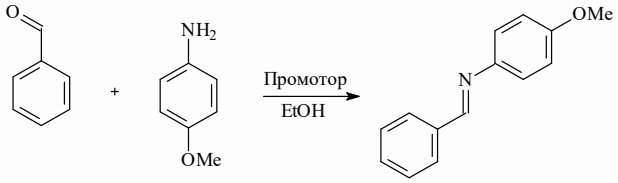


Figure 8. Synthesis of N-benzylidene-4-methoxybenzylamine

Japanese researchers Yasuhiro Shiraishi and his colleagues developed new catalytic nanoparticles (Pt@TiO_2) with Pt loaded on TiO_2, which enable the synthesis of imines from alcohols and amines under UV irradiation (λ>300 nm) at room temperature. This newly discovered method has the following advantages [24]:

- The reaction occurs at room temperature;
- No additional harmful by-products;
- Collection of clean energy resource — H_2 gas.

ISSN 3030-3907

The reaction of benzyl alcohol with aniline at room temperature under UV irradiation and nanocatalyst yielded N-benzylideneaniline 1 in high yield, along with 3% of N-benzylphenylamine 2. The reaction equation is shown in Figure 9:

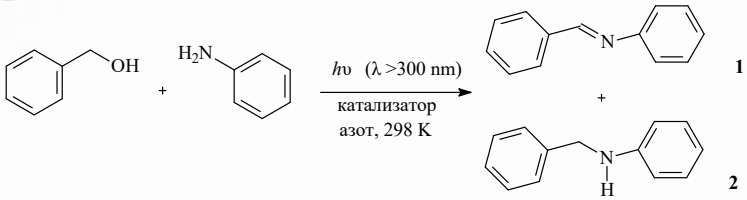


Figure 9. Synthesis of N-benzylideneaniline under UV irradiation and catalyst

3. Application Areas and Biological Activity of Schiff Bases

Organic compounds containing an imine or azomethine group (-C=N-), i.e. Schiff bases, are widely used in various fields such as analytical, inorganic, and organic chemistry. In particular: pigments and dye technologies [25], polymer stabilizers, catalysts [26], luminescence chemosensors [27,28], as intermediates in organic synthesis[29], corrosion inhibitors[30], application in solar energy fields has also been proposed. Furthermore, metal complexes of imines are widely used in pharmacology and biomedicine due to their numerous biological activities.[31] For example, antibacterial[32,33] antifungal[34,35], antimalarial[36], analgesic and anti- inflammatory, antiviral, antitumor[37,38]activities have been demonstrated.

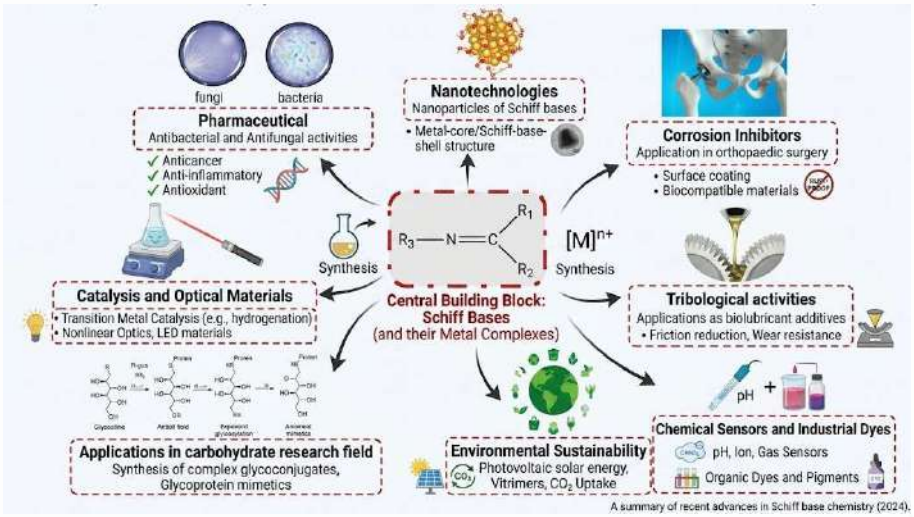


Figure 10. The diverse applications and recent advances in Schiff bases and their metal complexes.

Norwegian researchers used heavy metal complexes in their studies and conducted research on the isolation of ruthenium metal complexes. They used complexes of Mo, W, Re, Ru metals for increasingly developing olefin metathesis reactions at laboratory and industrial scale.Theyused the complexes of Mo, W, Re, Ru metals for olefin metathesis reactionsat laboratory and industrial scale.. As

ISSN 3030-3907

a result of their research, they successfully synthesized a ruthenium catalyst containing a bidentate Schiff base ligand used for olefin metathesis reactions in an efficient and environmentally safe mannerwas synthesized [39]. The synthesis of new generation Grubbs catalysts containing Schiff bases is shown in Figure 11.

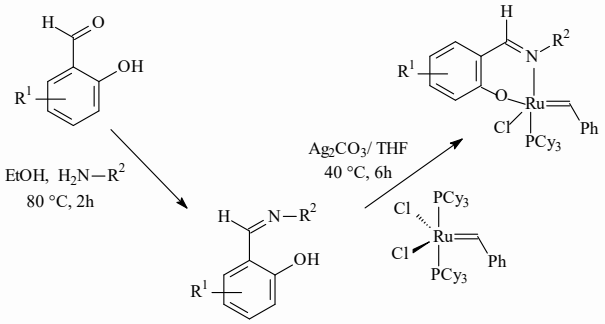


Figure 11. Schiff base ligand-containing new generation Grubbs Grubbs catalyst synthesis

The new class of catalysts obtained exhibit high thermal stability, which is of great significance. The gradual deterioration of the properties and characteristics of a metal or alloy as a result of its chemical or electrochemical interaction with the environment is called corrosion. Schiff bases are a widely studied class of organic compounds that exhibit effective **anti-corrosion** properties. The corrosion inhibition mechanism is based on the adsorption of the imine group onto the metal surface [40,41].

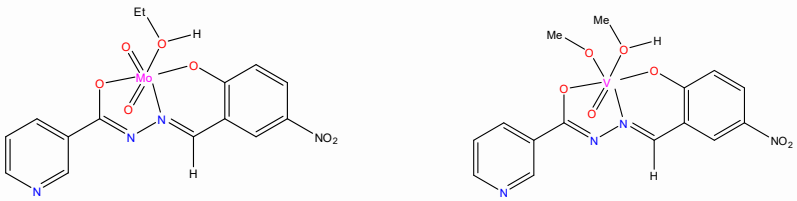


Figure 12. Chemical structures of the synthesized Mo and V metal complexes (catalysts) based on Schiff base ligands.

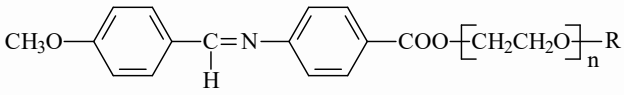
The imine group adsorbs onto the metal surface through its electron-rich center and forms a protective anti-corrosion coating layer. The π-acceptor property of the imine group ensures the formation of strong bonds with metal ions. Due to this property, compounds containing an imine group protect various metal-electrolyte systems, steel, and other alloys from corrosionπ-acceptor property ensures strong bond formation with metal ions. Due to this property, imine-containing compounds protect various metal-electrolyte systems, steel and other alloys from corrosion [42].

The strength of adsorption of Schiff bases on a metal surface depends on the electronic nature of the substituents. Molecules containing electron-donating groups (-OH, -OR, -NH_2, -NMe_2, -SH) in their molecular structure generally enhance corrosion inhibition efficiency. On the contrary, electron-withdrawing

ISSN 3030-3907

groups such as -COOH, -NO_2, -CN decrease the anti-corrosion ability of the molecule [30].

Egyptian scientists applied Schiff bases obtained from condensation of p-aminobenzoic acid with aromatic aldehydes as effective inhibitors against aluminum corrosion in acidic conditions. They also found that it can be used against corrosion of steel, iron, and copper [43]. They studied the inhibition activity of products by modifying the synthesized Schiff base with alkyl chains of various lengths as shown in Figure 13 [44].



n= 9,45 ва 68 этилен оксиди бирликлари
R= деканоат, олеат, гексадеканоат

Figure 13. Structure of nonionic Schiff base amphiphiles

Nigerian researchers synthesized new Schiff bases from the condensation of 3-hydroxy-4-methoxybenzaldehyde, 2-hydroxy-1-naphthaldehyde with3-aminobenzoic acid and studiedSchiff basessynthesized. The efficiency of corrosion inhibition of steel in 1.0 M HCl medium was studied [45]. Figure 14 shows the structure of a Schiff base compound with high efficiency in various electrolyte media for mild steel [46].

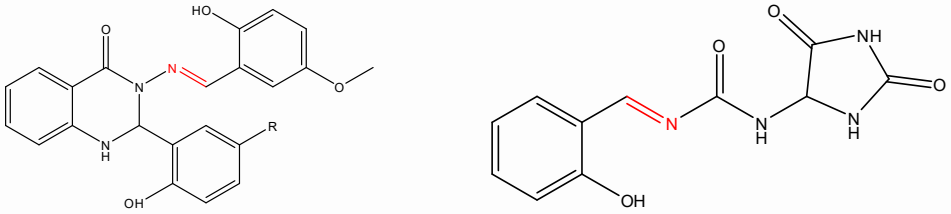


Figure 14. Imin compounds used as corrosion inhibitors for mild and carbon steel.

Schiff bases and their metal complexes are widely used in various [47] and detecting gases selectively and with high sensitivity, due to which they are used in various **sensor technologies** widely. Fluorescent and chemosensors based on Schiff bases are used to detect heavy metal ions such as Zn^{2+}, Cu^{2+}, Fe^{3+}, Al^{3+}, Pb^{2+}, Hg^{2+} [48] environmental gases such as NO_2, CO, NH_3 [49] pH levels, solvent composition, and various biological molecules. As a result of the interaction between a metal ion and a ligand, the optical or electrochemical properties of the complex such as color, conductivity, or fluorescence change, which serves for quantitative determination of pollutants in environmental samples, solvent analysis, or pH analysis.

Italian scientists studied the anticancer activity of Schiff bases and presented evidence of their highly effective action [50] Numerous studies have proven that metal complexes of Schiff bases show higher biological activity compared to the Schiff base molecule alone [51,52]. Among them, the Copper(II)

complex of a Schiff base showed strong antioxidant and anticancer activity [53]. Palladium(II), platinum(II), zinc(II), chromium(III) metal complexes of Schiff bases have been found to exhibit anticancer activity [54]. Complexes exert their activity by binding to the DNA or enzymes of cancer cells involved in proliferation.

The presence of lone pair electrons on the nitrogen atom in the azomethine part gives Schiff bases strong chelating ability. Due to the high flexibility and chelating ability of the imine group, they are considered interesting ligands in coordination chemistry [55].

CONCLUSION,

The ability of the imine group (-C=N-) to form strong coordination bonds with organic molecules and metal ions has led to the wide-scale application of these compounds. In the future, it is expected to play an important role in further improving ligand design and green synthesis methods and creating new functional materials. Environmental impact: According to the research conclusion, green synthesis methods (including microwave method) are superior to traditional methods both ecologically and economically, as they reduce energy consumption and simplify the product purification process. The ultrasonic method eliminates the drawbacks of traditional methods for obtaining imines such as complex procedures, long reaction times, and use of large amounts of toxic solvents.

REFERENSES

1. Przybylski P. et al. Biological properties of Schiff bases and azo derivatives of phenols //Current Organic Chemistry. – 2009. – T. 13. – №. 1. – P. 668-680.
2. Subasi N. T. A Comprehensive Review on Schiff Bases: Development Process, Green Synthetic Strategies, and Versatile Applications //Schiff Bases-Recent Developments and Application Areas. – 2025.
3. Boulechfar C. et al. Schiff bases and their metal Complexes: A review on the history, synthesis, and applications //Inorganic Chemistry Communications. – 2023. – T. 150. – C. 110451.
4. Asatkar A. K., Tripathi M., Asatkar D. Salen and related ligands //Stability and Applications of Coordination Compounds. – 2020. – C. 99-116.
5. Ovdenko V. N., Syromyatnikov V. G., Kolendo A. Yu. Polyazomethines. Synthesis, properties and application (review) // Polymer materials and technologies. - 2017. - Vol. 3. - No. 1. - P. 6-31.
6. Fabbrizzi L. Beauty in chemistry: making artistic molecules with Schiff bases //The Journal of Organic Chemistry. – 2020. – T. 85. – №. 19. – C. 12212-12226.
7. Chichak K. S. et al. Molecular borromean rings //Science. – 2004. – T. 304. – №. 5675. – C. 1308-1312.

ISSN 3030-3907

8. Pentecost C. D. et al. Making molecular Borromean rings. A gram-scale synthetic procedure for the undergraduate organic lab //Journal of chemical education. – 2007. – T. 84. – №. 5. – C. 855.
9. Chakraborti A. K., Bhagat S., Rudrawar S. Magnesium perchlorate as an efficient catalyst for the synthesis of imines and phenylhydrazones //Tetrahedron letters. – 2004. – T. 45. – №. 41. – P. 7641-7644.
10. Panneerselvam P. et al. Synthesis of Schiff bases of 4-(4-aminophenyl)-morpholine as potential antimicrobial agents //European journal of medicinal chemistry. – 2005. – T. 40. – №. 2. – P. 225-229.
11. Dalpozzo R. et al. Erbium (III) triflate: A valuable catalyst for the synthesis of aldimines, ketimines, and enaminones //Synthesis. – 2006. – T. 2006. – №. 07. – P. 1127-1132.
12. Naeimi H., Salimi F., Rabiei K. Mild and convenient one pot synthesis of Schiff bases in the presence of P2O5/Al2O3 as new catalyst under solvent-free conditions //Journal of Molecular Catalysis A: Chemical. – 2006. – T. 260. – №. 1-2.–P.100-104.
13. Kulkarni A., Patil S. A., Badami P. S. Synthesis, characterization, DNA cleavage and in vitro antimicrobial studies of La (III), Th (IV) and VO (IV) complexes with Schiff bases of coumarin derivatives //European Journal of medicinal chemistry. – 2009. – T. 44. – №. 7. – P. 2904-2912.
14. Rangaswamy V., Renuka S., Venda I. Synthesis, spectral characterization and antibacterial activity of transition metal (II) complexes of tetradentate Schiff base ligand //Materials Today: Proceedings. – 2022. – T. 51. – C. 1810-1816.
15. Boulechfar C. et al. Schiff bases and their metal Complexes: A review on the history, synthesis, and applications //Inorganic Chemistry Communications. – 2023. – T. 150. – C. 110451.
16. Bhusnure O. G. et al. Innovative Green synthesis of Schiff bases and their Antimicrobial Activity //J. Pharm. Res. – 2015. – T. 9. – №. 12. – C. 670.
17. Manjare S. B. et al. Microwave-assisted rapid and green synthesis of Schiff bases using cashew shell extract as a natural acid catalyst. ACS Omega 8: 2023 473–479.
18. Lindström U. M. Stereoselective organic reactions in water //Chemical Reviews. – 2002. – T. 102. – №. 8. – P. 2751-2772.
19. Wahab A., Haider S. S., Mahmood I. Synthesis of Schiff bases from natural products and their remarkable antimicrobial and antioxidant activity //FUUAST Journal of Biology. – 2014. – T. 4. – №. 1. – C. 27-32.
20. Yadav G., Mani J. V. Green synthesis of Schiff bases by using natural acid catalysts //International Journal of Science and Research. – 2015. – T. 4. – №. 2. – C. 121-127.

ISSN 3030-3907

21. Alikhani A. Lemon juice as a natural catalyse for synthesis of Shiff's base: a green chemistry approach //International Journal Of Advanced Engineering Research And Science. – 2018.
22. Saeed S. E. S. et al. Synthesis and characterization of metal complexes based on aniline derivative Schiff base for antimicrobial applications and UV protection of a modified cotton fabric //Coatings. – 2022. – Т. 12. – №. 8. – С. 1181.
23. Guzen K. P. et al. Eco-friendly synthesis of imines by ultrasound irradiation //Tetrahedron Letters. – 2007. – Т. 48. – №. 10. – P. 1845-1848.
24. Shiraishi Y. et al. One-pot synthesis of imines from alcohols and amines with TiO 2 loading Pt nanoparticles under UV irradiation //Chemical Communications. – 2011. – Т. 47. – №. 16. – P. 4811-4813.
25. Abuamer K. M. et al. The role of aromatic Schiff bases in the dyes techniques //International Journal of Organic Chemistry. – 2014. – Т. 4. – №. 1. – С. 7-15.
26. Wang X. et al. A novel triphenylamine-based bis-Schiff bases fluorophores with AIE-Activity as the hydrazine fluorescence turn-off probes and cell imaging in live cells //Talanta. – 2020. – Т. 217. – С. 121029.
27. Berrones-Reyes J. C. et al. Quantum chemical elucidation of the turn-on luminescence mechanism in two new Schiff bases as selective chemosensors of Zn 2+: Synthesis, theory and bioimaging applications //RSC advances. – 2019. – Т. 9. – №. 53. – С. 30778-30789.
28. Musikavanhu B. et al. Strategies for improving selectivity and sensitivity of Schiff base fluorescent chemosensors for toxic and heavy metals //Molecules. – 2023. – Т. 28. – №. 19. – С. 6960.
29. De S., Jain A., Barman P. Recent advances in the catalytic applications of chiral schiff-base ligands and metal complexes in asymmetric organic transformations //ChemistrySelect. – 2022. – Т. 7. – №. 7. – С. e202104334.
30. Verma C., Quraishi M. A. Recent progresses in Schiff bases as aqueous phase corrosion inhibitors: Design and applications //Coordination Chemistry Reviews. – 2021. – Т. 446. – С. 214105.
31. Ceramella J. et al. A review on the antimicrobial activity of Schiff bases: Data collection and recent studies //Antibiotics. – 2022. – Т. 11. – №. 2. – С. 191.
32. Da Silva C. M. et al. Schiff bases: A short review of their antimicrobial activities //Journal of Advanced research. – 2011. – Т. 2. – №. 1. – С. 1-8.
33. Chohan Z. H. et al. Metal based biologically active compounds: Design, synthesis, and antibacterial/antifungal/cytotoxic properties of triazole-derived Schiff bases and their oxovanadium (IV) complexes //European journal of medicinal chemistry. – 2010. – Т. 45. – №. 7. – С. 2739-2747.

ISSN 3030-3907

34. Hameed A. et al. Schiff bases in medicinal chemistry: a patent review (2010-2015) //Expert opinion on therapeutic patents. – 2017. – T. 27. – №. 1. – C. 63-79.
35. Kumar R. et al. Synthesis, antibacterial and antifungal activities of Schiff base rare earth metal complexes: a review of recent work //Journal of Coordination Chemistry. – 2023. – T. 76. – №. 9-10. – C. 1065-1093.
36. Iacopetta D. et al. Newly synthesized imino-derivatives analogues of resveratrol exert inhibitory effects in breast tumor cells //International journal of molecular sciences. – 2020. – T. 21. – №. 20. – C. 7797.
37. Iacopetta D. et al. Newly synthesized imino-derivatives analogues of resveratrol exert inhibitory effects in breast tumor cells //International journal of molecular sciences. – 2020. – T. 21. – №. 20. – C. 7797.
38. Sun Y. et al. Pt (II) and Au (III) complexes containing Schiff-base ligands: A promising source for antitumor treatment //European journal of medicinal chemistry. – 2021. – T. 211. – C. 113098.
39. Occhipinti G., Jensen V. R., Bjørsvik H. R. Green and efficient synthesis of bidentate Schiff base Ru catalysts for olefin metathesis //The Journal of Organic Chemistry. – 2007. – T. 72. – №. 9. – P. 3561-3564.
40. Satpati S. et al. Adsorption and anti-corrosion characteristics of vanillin Schiff bases on mild steel in 1 M HCl: experimental and theoretical study //RSC advances. – 2020. – T. 10. – №. 16. – C. 9258-9273.
41. Ma L. et al. Corrosion inhibition of Schiff bases for Mg-Zn-Y-Nd alloy in normal saline: Experimental and theoretical investigations //Corrosion Science. – 2021. – T. 184. – C. 109268.
42. Madani A. et al. Synthesis, density functional theory study, molecular dynamics simulation and anti-corrosion performance of two benzidine Schiff bases //Journal of Molecular Structure. – 2021. – T. 1235. – C. 130224.
43. Emregül K. C., Atakol O. Corrosion inhibition of iron in 1 M HCl solution with Schiff base compounds and derivatives //Materials Chemistry and Physics. – 2004. – T. 83. – №. 2-3. – P. 373-379.
44. Negm N. A., Zaki M. F. Structural and biological behaviors of some nonionic Schiff-base amphiphiles and their Cu (II) and Fe (III) metal complexes //Colloids and Surfaces B: Biointerfaces. – 2008. – T. 64. – №. 2. – P. 179-183.
45. Okey N. C. et al. Evaluation of some amino benzoic acid and 4-aminoantipyrine derived Schiff bases as corrosion inhibitors for mild steel in acidic medium: Synthesis, experimental and computational studies //Journal of Molecular Liquids. – 2020. – T. 315. – P. 113773.

ISSN 3030-3907

46. Gürten A. A. et al. The effect of temperature and concentration on the inhibition of acid corrosion of carbon steel by newly synthesized Schiff base //Journal of Industrial and Engineering Chemistry. – 2015. – T. 27. – C. 68-78.
47. Taha A. et al. Recent developments in Schiff base centered optical and chemical sensors for metal ion recognition //Journal of Molecular Liquids. – 2024. – T. 401. – C. 124678.
48. Kumar A. et al. Colorimetric and fluorescent Schiff base sensors for trace detection of pollutants and biologically significant cations: a review (2010–2021) //Microchemical Journal. – 2022. – T. 181. – C. 107798.
49. Zhang M. et al. Fabricating a hydroxynaphthalene benzophenone Schiff base into a wearable fluorescent sensor for point-of-care sensing of volatile organic compounds //Dyes and Pigments. – 2022. – T. 205. – C. 110561.
50. Iacopetta D. et al. Schiff bases: Interesting scaffolds with promising antitumoral properties //Applied Sciences. – 2021. – T. 11. – №. 4. – C. 1877.
51. Howsaui H. B. et al. Synthesis, structural investigations, molecular docking, and anticancer activity of some novel Schiff bases and their uranyl complexes //Biomolecules. – 2021. – T. 11. – №. 8. – C. 1138.
52. Pervaiz M. et al. Azo-Schiff base derivatives of transition metal complexes as antimicrobial agents //Coordination Chemistry Reviews. – 2021. – T. 447. – C. 214128.
53. Hajrezaie M. et al. A Schiff base-derived copper (II) complex is a potent inducer of apoptosis in colon cancer cells by activating the intrinsic pathway //The Scientific World Journal. – 2014. – T. 2014. – №. 1. – C. 540463.
54. Bazsefidpar P. et al. Anti-proliferative impact of three Schiff base platinum (II) complexes against human breast cancer cell line //Journal of Research in Pharmacy. – 2022. – T. 26. – №. 6. – C. 1665-1675.
55. Catalano A. et al. A review on the advancements in the field of metal complexes with Schiff bases as antiproliferative agents //Applied Sciences. – 2021. – T. 11. – №. 13. – C. 6027.

ISSN 3030-3907