REPUBLIC OF AZERBAIJAN

On the rights of the manuscript

ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

STUDY OF CO_2 CORROSION KINETICS WITH THE PARTICIPATION OF NATURAL ORGANIC ACIDS, AND ITS RELATION TO BIO- AND ATMOSPHERIC CORROSION

Speciality: 3303.01 – Chemical technology and engineering

Field of science: Technical sciences

Applicant: **Nihad Yusif Alimadatli**

Baku – 2025

The work was performed at the laboratory of «Corrosion inhibitors and conservation materials» of the Institute of Petrochemical Processes named by acad. Y.H.Mammadaliyev of Ministry of Science and Education Republic of Azerbaijan

Scientific supervisor: PhD in technical sciences, Associate professor
Nigar Shikar Rzayeva

Official opponents: Doctor of Technical Sciences, Professor
Fariz Ali Amirli
Doctor of Technical Sciences, Associate Professor
Narmina Rufat Abdullayeva
Doctor of Technical Sciences, Associate Professor
Yulduz Boyuk Agha Ramazanova

Dissertation council ED 1.17 of Supreme Attestation Commision under the President of the Republic of Azerbaijan operating at the Institute of Petrochemical Processes named after acad. Y.H.Mammadaliyev of the Ministry of Science and Education Republic of Azerbaijan

Chairman of the Dissertation council: Doctor of technical sciences, associate professor
Nizami Ibragim Mursalov

Scientific Secretary of the Dissertation Council: Doctor of technical sciences, associate professor
Zaur Zabil Aghamaliyev

Chairman of the scientific seminar: Doctor of technical sciences, associate professor
Sayyara Gulam Aliyeva

GENERAL NATURE OF THE WORK

The relevance of the topic and the degree of development

With the rapid development of industrialization, aviation, surface transportation, shipping, and the energy sector, the amount of aggressive components released into the atmosphere and natural water bodies has sharply increased. At the same time, the scale of numerous processes conducted under severe operating conditions—such as high velocities, elevated temperatures, high pressures, and turbulence—continues to expand. As a result, metallic equipment and installations are increasingly subjected to intensive corrosion processes. The chemical composition of the metals used is also one of the key factors influencing the rate of corrosion.

It should be noted that corrosion processes are hazardous for several reasons: the service life of equipment is drastically reduced, the frequency and cost of routine maintenance operations increase, idle downtime becomes more frequent, and both minor and major accidents occur. These accidents, in turn, often lead to severe and long-lasting environmental contamination. [1]

Special attention must be given to the protection of military and agricultural equipment from atmospheric corrosion, as such equipment is often stored for extended periods under conditions that make it particularly susceptible to damage.

Beginning in the 1940s, extensive work has been carried out in the world's leading industrial nations, including Azerbaijan, on the creation of corrosion protection systems, the study of their mechanisms of action, the development of production technologies, and their practical implementation. As a result, a number of scientifically significant solutions have been applied. However, a complete resolution of the corrosion problem has not yet been achieved. Furthermore, due to serious emerging ecological challenges, the requirements for proposed reagents and systems have become significantly more stringent: the reagents must have minimal

---

Abbasov, V.M., & Aghamaliyeva, D.B. (2023). Microbiological Corrosion and Methods of Its Control. Baku: Elm. 276 p. (in Azerbaijan) environmental impact, be multifunctional, be produced using simple and waste-free technology, be based on energy-efficient processes, and, wherever possible, be derived from renewable raw materials.

Our research has been devoted to the development of reagents and preservation fluids that meet, to the greatest possible extent, the above-mentioned requirements.

Object and subject of research

This study represents a systematic investigation into the utilization of natural petroleum acids obtained as a by-product from the kerosene fraction of the Baku crude oil blend. The research encompassed the synthesis of natural petroleum acids, the fractionation of these acids into narrow distillation cuts, and the subsequent synthesis of a series of amine complexes based on these fractions. The synthesized complexes were comprehensively evaluated for their effectiveness as reagents against hydrogen sulfide (H_2S) corrosion, carbon dioxide (CO_2) corrosion, as well as for their ability to inhibit the metabolic activity of sulfate-reducing bacteria (SRB). In addition, the study addressed the formulation of preservation fluids derived from the synthesized amine complexes, thus contributing to the development of multifunctional, environmentally responsible corrosion protection technologies.

Goals and objectives of the study

The objective of the research was to determine the mechanism of corrosion processes in certain aggressive media, to identify the main influencing factors, and to develop multifunctional reagents and preservation fluids capable of maximally retarding these processes. To achieve this objective, the following tasks were carried out:

- Natural petroleum acids (NPA) free of hydrocarbon admixtures were obtained from the sodium salts of NPA, which are produced as a by-product of the kerosene fraction of Baku crude oil blend;
- Four narrow fractions of NPA were separated, and their physicochemical properties were studied;
- Complexes of NPA with various nitrogen-containing organic compounds were synthesized at 20, 40, 60, and 80 °C;
- Ten-percent solutions of the synthesized complexes were

prepared in a solvent consisting of 70 % isopropyl alcohol (IPA) and 30 % water;

- The effect of the synthesized complexes on the hydrogen sulfide corrosion of St-3 steel specimens was studied in a biphasic water:kerosene medium (9:1 volume ratio, containing 500 mg/L H_2S); the dependence of the inhibitor efficiency on the synthesis temperature of the reagent and the size of the hydrocarbon radical of the NPA was investigated;
- The influence of the synthesized complexes on the metabolic activity of sulfate-reducing bacteria (SRB) was studied;
- Compositions were prepared by adding 10 % of the synthesized complexes to T-30 oil distillate and were investigated as preservation fluids; the tests were carried out in a “Г-4” humidity chamber, in Caspian Sea water, and in 0.001 % H_2SO_4 solution.

Research methods

The acid numbers of both the bulk and narrow fractions of natural petroleum acids (NPA) were determined in accordance with GOST 5985-79. Infrared (IR) and nuclear magnetic resonance (NMR) spectra of the isolated NPA and their synthesized complexes were recorded. The effect of the complex solutions on hydrogen sulfide (H_2S) corrosion was studied at room temperature for a duration of six hours using St3 steel specimens.

The kinetics of CO_2 corrosion were investigated using a *CorrTest* potentiostat at 50 °C in a 1 % NaCl solution saturated with CO_2, employing a C1018 steel electrode.

Testing of the preservation fluids was carried out in compliance with the requirements of GOST 9054-75.

The main provisions put forward for defence

A 20–25 % aqueous solution of the sodium salt of NPA, obtained as a by-product from the kerosene fraction of Baku crude oil blend, was purified of hydrocarbon admixtures to yield NPA. Its narrow fractions were separated, and their physicochemical properties were studied. Various amine complexes of these fractions were synthesized at different temperatures, and solutions of the complexes were prepared.

The prepared solutions were investigated for their effects on H_2S

and CO_2 corrosion, as well as on the metabolic activity of sulfate-reducing bacteria (SRB). Preservation fluids were prepared on the basis of the synthesized complexes and T-30 oil distillate and were subsequently studied.

Scientific novelty of the research.

- NPA free of hydrocarbon ballast and its four narrow fractions were obtained from the sodium salt of NPA separated from the kerosene fraction of the Baku crude oil blend; based on these, complexes with various alkylamines ($C_4H_9NH_2$, $C_8H_{17}NH_2$, $(C_4H_9)_2NH$, $C_7H_{15}NH_2$, $CH_2(NH_2)_2$, $(C_2H_5)_2NH$, $(C_5H_{11})_2NH$) were synthesized. Ten-percent solutions of the complexes were prepared in 70 % aqueous isopropyl alcohol (IPA), and their physicochemical properties were studied.
- It was established that synthesizing the complexes at 80 °C has a positive effect on their performance. This is attributed to the fact that, under the influence of temperature, the nitrogen atom of the amine becomes more protonated during interaction with NPA, which ensures stronger adsorption of the complex molecule onto the protected metal surface.
- The effect of the solutions of ethylenediamine, butylamine, dibutylamine, heptylamine, and octylamine complexes of NPA fractions I, II, III, and IV on CO_2 corrosion was investigated. It was established that the butylamine complex of Fraction I provides higher protection against CO_2 corrosion compared to the solutions of other amine complexes (98.8 % at 1000 mg/L).
- Various amine complexes of NPA were obtained, incorporated into T-30 oil distillate at 10.0 % to prepare preservation fluids, and it was established that most of them are highly effective as preservation fluids. It was also determined that the synthesis temperature plays an important role: among complexes synthesized at 20, 40, 60, and 80 °C, those synthesized at 80 °C proved to be more effective components of preservation fluids.

Theoretical and practical significance of the study

It was established that high-quality inhibitor-biocides and preservation fluids can be created on the basis of NPA. The effect of molecular size and whether the alkylamines are mono- or dialkyl on the efficiency of the reagents was investigated, and certain generalizations were made. The theoretical results obtained may be used in the future for the development of more effective reagents.

If the proposed reagents and preservation fluids are manufactured and applied domestically, this would, on the one hand, ensure the efficient utilization of NPA, a by-product of oil refining, and, on the other hand, solve corrosion problems in various industrial sectors, agriculture, and the defense industry.

Approval and implementation

A total of 12 works related to the dissertation have been published, including 7 articles and 5 theses.

The main results of the dissertation were presented and discussed at the following scientific conferences:

Akademician Maharram Ali oglu Mamedyarov's 100th Anniversary International Scientific Conference *"Modern Problems of Petrochemistry and Lubricant Technology"* (Baku, 2024); International Conference dedicated to the 60th anniversary of the establishment of the Department of Technology of Organic Substances and High-Molecular Compounds *"Modern Problems of Macromolecular Compound Technology"* (Baku, 2024); International Scientific Conference *"Monomers and Modern Problems of Petrochemistry"* dedicated to the 110th anniversary of Academician Soltan Jafar oglu Mehdiyev (Baku, 2024); Third International Bilateral Workshop on Natural Science Between Dokuz Eylul University and the Azerbaijan National Academy of Sciences (Baku, 2024).

Name of the organization where the dissertation work was performed

The submitted dissertation work was performed at the Institute of Petrochemical Processes named after academician Y.H.Mammadaliyev of the Ministry of Science and Education of the Republic of Azerbaijan.

Personal participation of the author

The author directly participated in the collection of materials related to the dissertation, their analysis and generalization, the execution of laboratory research, the systematization of the work carried out, as well as in the writing and preparation of the articles, theses, and the dissertation itself.

The total volume of the dissertation, indicating the volume of the structural sections of the dissertation separately: The dissertation is 160 pages in length and consists of an **Introduction**, **eight chapters**, **Conclusions**, 120 literature references, and, including the list of abbreviations, 32 tables, 62 figures, 9 graphs, and 7 schemes. The total volume of the dissertation (excluding figures, tables, graphs, appendices, and the list of references) comprises 188,184 characters (Introduction – 10,352 characters; **Chapter I** – 41,170 characters; **Chapter II** – 20,610 characters; **Chapter III** – 10,495 characters; **Chapter IV** – 22,615 characters; **Chapter V** – 13,510 characters; **Chapter VI** – 6,925 characters; **Chapter VII** – 54,380 characters; **Chapter VIII** – 3,423 characters; and Conclusions – 4,704 characters).

Introduction analyzes the relevance of the problem, the objective of the research, and the state of its solution, and highlights the importance of addressing the posed scientific problem.

Chapter I provides an analytical review of scientific works concerning corrosion problems and their solutions, emphasizing the necessity of conducting research in this field.

Chapter II presents information on the selected raw materials, synthesis methods, and analysis and testing techniques used in the research.

Chapter III describes the preparation of various complexes and salts of NPA, their spectral analyses, the preparation of their solutions, and their physicochemical properties.

Chapter IV presents an analysis of the results of studies on the effect of NPA amine complexes and salts on the kinetics of CO_2 corrosion.

Chapter V analyzes the results of studies on the effect of solutions of complexes and salts obtained from various NPA fractions on H_2S corrosion in a biphasic (water:kerosene) medium.

Chapter VI presents the results of studies on the bactericidal effect of NPA alkylamine complex solutions against SRB.

Chapter VII provides the results of tests of complexes synthesized with various alkylamines at different temperatures and of preservation fluids prepared on the basis of T-30 oil distillate. The reasons for variations in the protective efficiency of the preservation fluid, depending on the structure of the amine complex, the size of the alkyl radicals, and the synthesis temperature of the complexes, are explained.

Chapter VIII presents the principal scheme for the technology of producing multifunctional inhibitor-biocides and preservation fluids based on various NPA fractions and alkylamines.

At the end of the dissertation, the results reflecting the research conducted, a list of cited literature, and appendices are included.

MAIN CONTENT OF THE WORK

The analysis of the literature review can be summarized as follows: since CO_2 corrosion, H_2S corrosion, and microbiological corrosion processes are predominant in the oil and gas extraction and processing industries, the development and use of multifunctional corrosion inhibitors is advisable; during oil production, formation water is produced along with the oil, and the waters from different wells are extracted from varying depths and have different salt compositions. When these waters are mixed in a common tank, chemical equilibrium is disturbed and a salt deposition process occurs; therefore, this problem must also be taken into account when using corrosion inhibitors. The proposed inhibitors should be as harmless as possible, should not degrade the quality of the extracted oil, must be obtained through simple technology from readily available raw materials, and should not create antagonism with other reagents used.

Selection of Raw Materials for Reagent Synthesis The following main reagents and raw materials were used in the synthesis of nitrogen-containing complexes and salts with high adsorption properties: butylamine (BA, Germany), octylamine (OA, Germany), diethylamine (DEA, Germany), dibutylamine (DBA, Germany), dipentylamine (DPA, Germany), NaOH, KOH (Russia), and natural petroleum acid (NPA) of Azerbaijani origin.

The main physicochemical characteristics of the amines used in the preparation of the complexes are presented in Table 1.

Table 1.
Physicochemical Characteristics of the Amines Used

Indicator	Butylamine	Octylamine	Diethylamine	Dibutylamine	Dipentyl amine
1	2	3	4	5	6
Average molecular weight	73.14	129.25	73.14	129.25	157.31
Boiling point, °C (760 mm Hg)	78.0	175.0	55.5	159.0	205.0
Freezing point, °C	-49.0	-37.0	-50.0	-70.0	-59.0
Viscosity, $N \cdot s/m^2$	0.00046	0.0012	0.00037	0.00103	0.00145
Density at 20 °C, g/cm^3	0.74	0.79	0.71	0.78	0.79
Refractive index, n_D^{20}	1.398	1.425	1.377	1.426	1.428
pH (1 % solution)	11.5	11.1	12.1	11.3	11.0
Nitrogen content, %	19.2	10.8	19.2	10.8	9.6
Amine number, mg KOH/g	785.0	440.0	790.0	445.0	400.0
Mass fraction, % - Main substance - Total nitrogen - Water (max.)	 99.5 19.2 0.3	 98.7 10.8 0.5	 99.1 19.2 0.3	 98.5 10.8 0.4	 97.8 9.6 0.6

Four different fractions (I, II, III, and IV) of natural petroleum acids (NPA) obtained from the kerosene fraction of Baku crude oil blend were separated, and the synthesis of alkyl- and dialkylamine complexes based on these fractions was identified as one of the main objectives of the study. The selection of this direction was due to the scientific and practical significance of the potential application of the synthesized compounds as corrosion inhibitors in acidic media containing aggressive components such as hydrogen sulfide and carbon dioxide.

For this purpose, the total mixture of petroleum acids was fractionated under vacuum conditions, resulting in four different fractions. The main physicochemical characteristics of the separated acid fractions were analyzed, and the results obtained are presented in Table 2.

Table 2.

Physicochemical Characteristics of the Fractions Separated from NPA

Fractions of NPA	$t_{boiling.}$ °C atm.	$t_{boiling.}$°C vac. 2 mm Hg	Acid Number, mg KOH/ g	Average molecular weight, M_r
I	210-280	70-110	324.3	173
II	280-350	110-160	291.16	193
III	350-380	160-180	278	202
IV	380-450	180-240	235,6	238

Test Methods for Preservation Materials in Various Aggressive Media

The studies were carried out in accordance with the requirements of GOST 9054-75. For the tests, metal plates of "St3" steel with dimensions of 40–50 mm ± 0.3 mm and a thickness of 5.5 mm were prepared. Prior to use, the surfaces of the plates were mechanically cleaned, polished, and washed with organic solvents (gasoline or alcohol) and then dried. Each plate was then suspended using a polymer thread and immersed in the preservation fluid for 24 hours, after which it was dried for 1 hour under atmospheric conditions. The plates were subsequently tested in seawater, in a 0.001 % H_2SO_4 solution, and in a temperature-humidity chamber.

Synthesis of Amine Complexes and Salts of Various NPA Fractions

During the course of the research, four fractions (I, II, III, and IV) of natural petroleum acids (NPA) obtained from the kerosene fraction of the Baku crude oil blend were separated, and corresponding alkyl- and dialkylamine complexes were synthesized on the basis of these fractions. The following primary amines were used for the synthesis of the complexes: butylamine ($C_4H_9NH_2$), octylamine ($C_8H_{17}NH_2$), diethylamine ($(C_2H_5)_2NH$), dibutylamine ($(C_4H_9)_2NH$), and dipentylamine ($(C_5H_{11})_2NH$). For the preparation of the corresponding salts, sodium hydroxide (NaOH) and potassium hydroxide (KOH) were used as bases.

The synthesis of the complexes was carried out as follows:

During the reaction, natural petroleum acids and alkyl- or dialkylamines were taken in a 1:1 molar ratio and subjected to intensive stirring for 20–25 minutes, resulting in the synthesis of organic complexes. There was no need to supply external heat to the reaction, as it is exothermic and releases a large amount of energy. The resulting complexes were yellowish liquids with a yield of 99.1–99.8 %. General schemes of the synthesis of NPA complexes with alkyl- and dialkylamines in a 1:1 molar ratio are presented below (Schemes 1–3).

$$RCOOH + R'NH_2 \longrightarrow RCO\overset{-}{O}\overset{+}{N}H_3R'$$

Here: R = residue of natural petroleum acid, R' = C_4H_9, C_8H_{17}

Scheme 1. General Equation of the Synthesis Reaction of Natural Petroleum Acid Complexes with Alkylamines.

$$RCOOH + (R')_2NH \longrightarrow RCO\overset{-}{O}\overset{+}{N}H_2(R')_2$$

Here: R = residue of natural petroleum acid, R' = $(C_2H_5)_2$, $(C_4H_9)_2$, $(C_5H_{11})_2$,

Scheme 2. General Equation of the Synthesis Reaction of Natural Petroleum Acid Complexes with Dialkylamines.

$$RCOOH + NaOH \longrightarrow RCOONa + H_2O$$

$$RCOOH + KOH \longrightarrow RCOOK + H_2O$$

Scheme 3. General Equation of the Synthesis Reaction of Sodium and Potassium Salts of Natural Petroleum Acids.

The physicochemical properties of the solutions of reagents obtained from various fractions of natural petroleum acids are presented in Tables 3–6.

Table 3.

Physicochemical Properties of 10 % Solutions of Amine Complexes and Corresponding Salts of NPA Fraction I in 70 % IPA

Names of Indicators:	Samples						
	N-1	N-2	N-3	N-4	N-5	N-6	N-7
Density (g/cm³)	0.8862	0.8833	0.8913	0,8908	0,8720	0,8952	0,8834
Refractive Index (at 20°C)	1.3803	1.3811	1.3813	1,3809	1,4400	1,3827	1,3804
Freeze temp., °C	-38	-44	-48	-40	-42	-50	-45
Acid number mg·KOH/g	-	-	-	-	-	-	-

As seen from Table 3, the 10 % solution of the sodium salt of NPA Fraction I in 70 % IPA has a lower freezing point and solidifies at −50 °C. Among the amine complex solutions presented in the same table, the solution of the diethylamine complex of NPA Fraction I freezes at a lower temperature (−48 °C) compared to the other amine complexes.

Table 4.

Physicochemical Properties of 10 % Solutions of Amine Complexes and Corresponding Salts of NPA Fraction II in 70 % IPA

Names of indicators:	Samples						
	N-8	N-9	N-10	N-11	N-12	N-13	N-14
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Density (g/cm³)	0,8815	0,8672	0,8381	0,8678	0,8742	0,8698	0,8746
Refractive Index (at 20°C)	1,4340	1,4405	1,4381	1,4362	1,4393	1,3814	1,3794
Freeze temp., °C	-44	-50	-44	-42	-42	-54	-45
Acid Number mg·KOH/g	-	-	-	-	-	-	-

As seen from the data in Table 4, the 10 % solution of the sodium salt of NPA Fraction II in 70 % IPA has a lower freezing point (−54 °C).

Among the amine complex solutions of NPA Fraction II, the octylamine complex solution has the lowest freezing point, at −50 °C.

Table 5.

Physicochemical Properties of 10 % Solutions of Amine Complexes and Corresponding Salts of NPA Fraction III in 70 % IPA

Names of indicators:	Samples					
	N-15	N-16	N-17	N-18	N-19	N-20
Density (g/cm³)	0,8815	0,8831	0,8846	0,8762	0,8906	0,9004
Refractive Index (at 20°C)	1,4687	1,3826	1,3820	1,3838	1,3817	1,3800
Freeze temp., **°C**	-35	-50	-46	-43	-50	-48
Acid Number mg·KOH/g	-	-	-	-	-	-

Among the solutions of complexes and salts of NPA Fraction III, the solutions with code numbers 16 and 19 have the lowest freezing points, both solidifying at −50 °C. The solution with code number 16 corresponds to the diethylamine complex, while the solution with code number 19 corresponds to the sodium salt solution.

Table 6.

Physicochemical Properties of 10 % Solutions of Amine Complexes and Corresponding Salts of NPA Fraction IV in 70 % IPA

Names of indicators	Samples					
	N-21	N-22	N-23	N-24	N-25	N-26
Density (g/cm³)	0,8792	0,8790	0,8823	0,8834	0,8938	0,8994
Refractive Index (at 20°C)	1,3821	1,3821	1,3809	1,3824	1,3823	1,3813
Freeze temp., **°C**	-45	-50	-46	-42	-58	-51
Acid Number mg·KOH/g	-	-	-	-	-	-

As seen from Table 6, the solutions with code numbers 25, 26, and 22 have lower freezing points, being −58 °C, −51 °C, and −50 °C, respectively.

Study of the Effect of Amine Complexes and Salts Obtained from Various NPA Fractions on the Corrosion Process in a CO_2 Medium Using the Tafel Method

The results obtained from the study of the effect of 10 % solutions of amine complexes and salts derived from NPA Fraction I in 70 % IPA on the corrosion process in a carbon dioxide medium, using the Tafel method, are presented in Table 7.

Table 7.

Results of the Study of the Effect of Amine Complexes and Salts Obtained from NPA Fraction I on the Corrosion Process Using the Tafel Method

Name of Substance	Concentration, ppm	E_{cor} mV	$\dot{I}_{corr}$ A/cm^2	Corrision rate, mm/year	Protection Efficiency, %
Without Inhibitor	–	-731	5.7576×10^{-5}	0.675	–
N-1 (Butylamine Complex)	500	-730	5.3056×10^{-6}	0.062	90.7
	1000	-670	5.763×10^{-7}	0.006	98.8
N-2 (Octylamine Complex)	500	-748	1.8098×10^{-5}	0.212	67.7
	1000	-742	8.8093×10^{-6}	0.103	84.9
N-3 (Diethylamine Complex)	500	-755	3.5405×10^{-5}	0.415	40.0
	1000	-731	4.2819×10^{-6}	0.050	92.5
N-4 (Dibutylamine Complex)	500	-745	1.4139×10^{-5}	0.165	75.8
	1000	-747	1.4545×10^{-5}	0.170	75.3
N-5 (Sodium Salt)	500	-786	3.0644×10^{-5}	0.359	50.0
	1000	-746	1.8173×10^{-5}	0.213	69.0
N-6 (Potassium Salt)	500	-743	1.6044×10^{-5}	0.188	72.5
	1000	-745	1.9231×10^{-5}	0.225	67.2

As seen from the table, in the control sample without inhibitor (blank test), the corrosion current density was 5.7576×10^{-5} A/cm^2, and the corrosion rate was 0.675 mm/year. These indicators demonstrate that the medium is aggressive toward carbon steel.

N-1 (NPA + Butylamine Complex).

Application of this complex at a concentration of 1000 ppm reduced I_{corr} to 5.763×10^{-7} A/cm^2, resulting in a corrosion rate of 0.006 mm/year, which corresponds to a protective efficiency of 98.8 %. This effect is associated with the electron-donating role of the primary amine group in the butylamine structure and its strong adsorption onto the metal surface when forming a complex with NPA. At the same time, the shift of E_{corr} from −731 mV to −670 mV indicates a weakening of anodic processes.

N-2 (NPA + Octylamine Complex).

The long alkyl chain of octylamine increases the hydrophobicity of the complex, restricting the penetration of ions in the corrosive medium to the metal surface. At a concentration of 1000 ppm, this complex exhibited a protective efficiency of 84.9 %. However, the solubility and adsorption ability of long-chain amines create certain limitations on the dense packing of molecules.

N-3 (NPA + Diethylamine Complex).

Although the protective efficiency at 500 ppm was only 40 %, at 1000 ppm it reached 92.5 %. This demonstrates a strong concentration dependence of the inhibitor effect. It should be noted that the two alkyl chains of the diethylamine molecule can somewhat weaken adsorption onto the metal surface; however, as the concentration of the inhibitor increases, a denser and more stable protective layer is formed.

N-4 (NPA + Dibutylamine Complex).

The protective efficiency of this complex ranged between 75–76 %. Although the presence of two butyl groups enhances spreading on the surface, conformational restrictions that affect molecular alignment reduce adsorption, resulting in lower protective efficiency.

Sodium (N-5) and Potassium (N-6) Salts of NPA.

The corrosion-inhibiting effect of these salts was weaker compared to the amine complexes. The sodium salt provided 69 % protection, while the potassium salt achieved a maximum of 72.5 %. This may be attributed to the fact that, in the salts, only the carboxylate anion interacts with the metal, whereas in the amine complexes the synergistic effect of both the proton-accepting nitrogen and the hydrophobic alkyl groups is present.

The results obtained indicate that amine complexes—particularly those of butylamine and diethylamine—can significantly suppress the corrosion process when applied at high concentrations. Data from the

Tafel curves confirm that these substances slow down both anodic and cathodic reactions, thereby reducing the rate of metal degradation and acting as highly efficient inhibitors.
The simple synthesis process of these complexes, their derivation from natural raw materials, and their environmental safety make them suitable for industrial-scale application.
The graphical representation of the Tafel curves for the inhibitors is presented below (Figure 1).

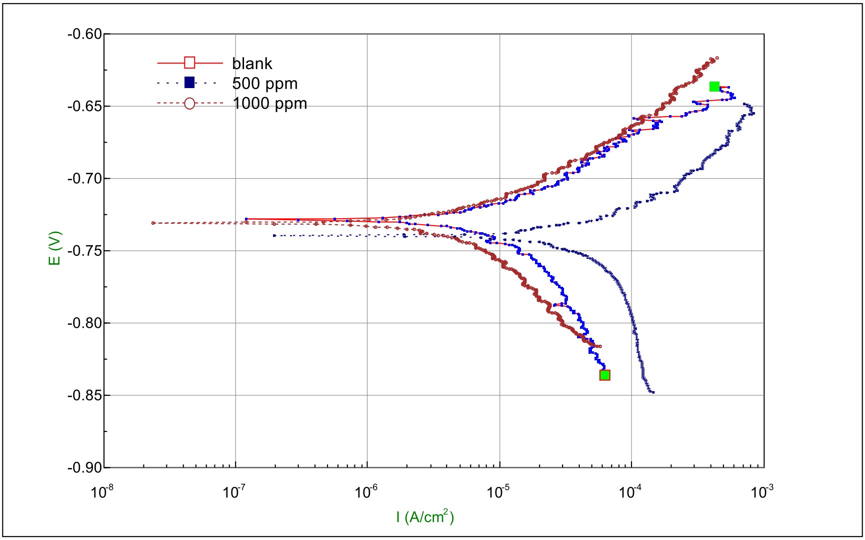


Figure 1. Tafel Polarization Curves of the 10 % Solution of the Butylamine Complex of NPA Fraction I in 70 % IPA

During the study, the effect of 10 % solutions of various amine complexes obtained from NPA Fraction II (prepared in 70 % isopropanol) on the corrosion processes of carbon steel in a CO_2-saturated 1 % NaCl medium was determined using the Tafel polarization method. The inhibitor concentrations were selected as 500 and 1000 ppm, and the results obtained were analyzed as presented in Table 8.

As seen from Table 8, the corrosion potential in the medium without inhibitor was −731 mV, the corrosion current density was 5.7576×10^{-5} A/cm², and the corrosion rate was 0.675 mm/year. These indicators were used as a baseline for comparing the effectiveness of the inhibitors..

Table 8.

Results of the Study of the Effect of Amine Complexes and Salts Obtained from NPA Fraction II on the Corrosion Process Using the Tafel Method

Name of Substance	Concentration, ppm	E_{cor} mV	$İ_{corr}$ A/cm^2	Corrision rate, mm/year	Protection Efficiency, %
Without Inhibitor	–	-731	5.7576×10^{-5}	0.675	–
N-7 (Butylamine Complex of NPA Fraction II)	500	-726	1.79×10^{-5}	0.210	68.6
	1000	-653	5.79×10^{-7}	0.0068	98.8
N-8 (Octylamine Complex of NPA Fraction II)	500	-697	7.6849×10^{-6}	0.09	85.9
	1000	-636	4.6593×10^{-7}	0.005	99
N-9 (Diethylamine Complex of NPA Fraction II)	500	-720	6.2556×10^{-6}	0.073	88.9
	1000	-672	7.57×10^{-7}	0.0088	98.5
N-10 (Dibutylamine Complex of NPA Fraction II)	500	-684	3.31×10^{-6}	0.062	90
	1000	-708	3.19×10^{-6}	0.037	94
N-11 (Dipentylamine Complex of NPA Fraction II)	500	-715	7.26×10^{-6}	0.0852	87
	1000	-700	4.16×10^{-6}	0.383	42
N-12 (Sodium Salt of NPA Fraction II)	500	-731	3.06×10^{-6}	0.035	94.6
	1000	-722	1.86×10^{-6}	0.021	96.7
N-13 (Potassium Salt of NPA Fraction II)	500	-723	2.25×10^{-6}	0.026	96
	1000	-724	2.51×10^{-6}	0.029	95.5

The effect of 10 % solutions of various amine complexes and Na^+ and K^+ salts obtained from NPA Fraction III in 70 % isopropanol (IPA) on the corrosion processes in a CO_2-saturated 1 % NaCl medium was investigated using the Tafel polarization method.

Similarly, the corrosion-inhibiting effect of 10 % solutions of amine complexes and Na^+ and K^+ salts obtained from NPA Fraction IV (prepared in 70 % isopropanol) on carbon steel in a CO_2-saturated 1 % NaCl solution was studied using the Tafel polarization method. In the inhibitor-free medium (at −731 mV potential), the corrosion current density was 5.7576×10^{-5} A/cm², and the corrosion rate was 0.675 mm/year.

Investigation of Amine Complexes of Various NPA Fractions as H_2S Corrosion Inhibitors

Ten-percent solutions of alkyl- and dialkylamine complexes of NPA Fractions I, II, III, and IV in 70 % isopropyl alcohol were used as inhibitors against the corrosion of Ct-3 grade steel specimens in an acidic medium.

During the investigation, the corrosion rate, inhibition coefficient, protection efficiency, and surface coverage coefficient of these compounds were analyzed, and the results were systematized and presented in the following table 9.

Table 9.

Results on the Protective Effect of 10 % Solutions of Alkyl- and Dialkylamine Complexes of NPA Fraction I in 70 % Isopropyl Alcohol on Ct-3 Steel in an H_2S Environment

Substances	Concen-tration, C, mg/*l*	Corrosion rate, ρ, g/m²·h	Inhibition Coefficient, γ	Protection Efficiency, Z %	Surface Coverage Coefficient, (θ)
Without Inhibitor	–	5.6898	–	–	–
NPA + Butylamine Complex (N-1)	1000 2000 3000 4000	4.3003 4,0573 2,8688 1.4065	1.32 1,4 1,9 4.05	23 29 50 75.3	0.23 0.29 0.50 0.75

NPA + Octylamine Complex (N-2)	1000	2.3102	2.45	60	0.60
	2000	1,7144	3,31	69,8	0,69
	3000	0,7377	7,71	87,03	0,87
	4000	0.1001	56.8	98.2	0.98
NPA + Diethylamine Complex (N-3)	1000	4.2121	1.34	24.2	0.24
	2000	3.3606	1.69	41	0.41
	3000	2.5409	2.24	55	0.55
	4000	1.2031	4.73	79	0.79
NPA + Dibutylamine Complex (N-4)	1000	2.4115	2.35	58	0.58
	2000	1,8442	3,08	67,5	0,67
	3000	0,8743	6,5	87,4	0,84
	4000	0.3027	18.9	95	0.95

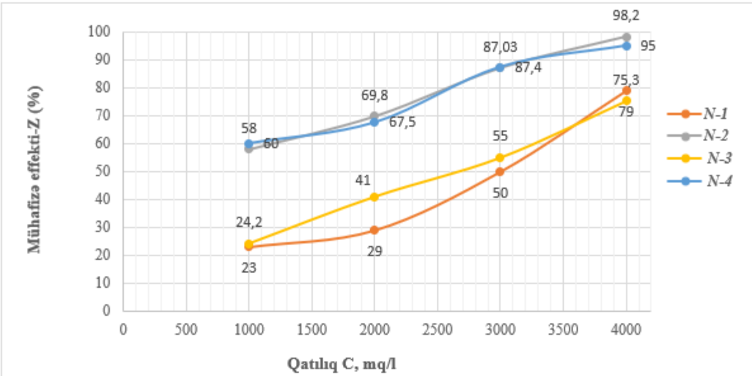


Figure 2. Graphical Representation of the Dependence of the Protection Efficiencies of 10 % Solutions of Amine Complexes of NPA Fraction I in 70 % IPA on Concentration

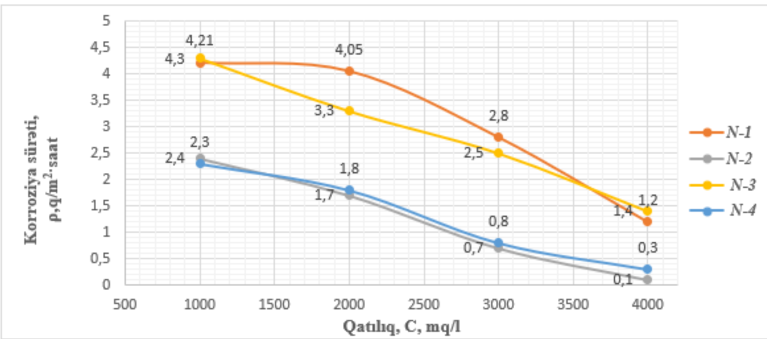


Figure 3. Graphical Representation of the Dependence of the Corrosion Rates of 10 % Solutions of Amine Complexes of NPA Fraction I in 70 % IPA on Concentration

With the application of these complexes, the inhibition coefficient (θ) increases significantly.

Investigation of the Bactericidal Properties of Alkyl- and Dialkylamine Complexes of NPA

Within the framework of the study, the bactericidal effect of certain alkyl- and dialkylamine complexes, whose inhibitory properties had been previously investigated, was examined. For this purpose, their effect against sulfate-reducing bacteria (Desulfovibrio desulfuricans) was studied under laboratory conditions in Postgate B medium.

The results of the experiments are presented in Table 10.

Table 10.

Results on the Bactericidal Effects of 10 % Solutions of Alkyl- and Dialkylamine Complexes of Various NPA Fractions in 70 % Isopropyl Alcohol

Conditional Name and Composition of the Complexes	Substance Concentration, C, mg/L	Number of Bacteria (cells/mL)	H_2S Content, mg/L	Bactericidal Effect, Z-%
1	2	3	4	5
N-1	15	10^1	2.5	99
	25	-	-	100
	50	-	-	100
N-2	15	-	-	100
	25	-	-	100
	50	-	-	100
N-3	15	-	-	100
	25	-	-	100
	50	-	-	100
N-4	15	-	-	100
	25	-	-	100
	50	-	-	100
N-5	15	10^1	24.8	90.2
	25	10^1	16.4	93.5
	50	-	-	100

1	2	3	4	5
N-6	15	10^{1}	2.8	98.9
	25	-	-	100
	50	-	-	100
N-7	15	10^{1}	2.4	99
	25	-	-	100
	50	-	-	100
N-8	15	-	-	100
	25	-	-	100
	50	-	-	100
N-9	15	10^{1}	3.1	98.7
	25	10^{1}	1.4	99.4
	50	-	-	100
N-10	15	-	-	-
	25	-	-	-
	50	-	-	-
N-11	15	10^{3}	2.9	98.8
	25	-	-	100
	50	-	-	100
N-12	15	-	-	100
	25	-	-	100
	50	-	-	100
Control I – H_2S Content in Medium Without SRB	24 mg/L			
Control II – H_2S Content in Medium With SRB	255 mg/L			
Control III – Number of Bacteria in Nutrient Medium	10^{8} cells/mL			

As seen from the table, the solutions of the octylamine and other complexes of NPA Fraction I, at a concentration of 15 mg/L, completely suppress the activity of SRB; no SRB cells remain in the medium, and no hydrogen sulfide is formed. The alkylamine complexes obtained from NPA Fraction II are relatively less effective: at a concentration of 15 mg/L, they exhibit bactericidal effects of 90.2 % and 98.9 %, respectively. It should also be noted that the dibutylamine complex of NPA is more effective than the butylamine complex.

The results of the study show that the solution of the butylamine complex of NPA Fraction III, when introduced into the medium at 15 and 25 mg/L, reduces the number of SRB cells from 10^8 to 10^1 in both cases, while the H_2S content decreases from 255 mg/L to 3.1 and 1.4 mg/L, respectively. This complex completely eliminates SRB cells and prevents H_2S formation only when used at a concentration of 50 mg/L.

The octylamine complex of NPA Fraction III is more effective than the heptylamine complex. Specifically, when introduced at 15 mg/L, the heptylamine complex reduces the SRB cell count in the medium from 10^8 to 10^3, and the H_2S content from 255 mg/L to 2.9 mg/L. Under the same conditions (15 mg/L), the octylamine complex solution completely eliminates SRB cells from the medium and prevents H_2S formation.

Investigation of Amine Complexes of Various NPA Fractions as Additives to Preservation Materials

The corrosion protection efficiencies of preservation fluids were tested (Tables 11–14) by adding complexes of NPA Fractions I, II, and III—obtained from the kerosene fraction of the Baku crude oil blend and synthesized with alkyl- and dialkylamines at various temperatures (room temperature, 40 °C, 60 °C, and 80 °C)—to mineral oil (T-30) at various percentage ratios.

From the overall analysis, the following conclusions were drawn:

- Amine complexes synthesized at 80 °C exhibited long-term and stable protective effects.
- Complexes synthesized from long-chain amines, such as octylamine and dibutylamine, demonstrated high efficiency.
- Complexes obtained on the basis of ethylenediamine showed relatively weaker effects.
- The temperature of 80 °C can be considered the optimal synthesis condition, as the resulting products exhibited advantages both in terms of corrosion resistance and physical stability.Thus, amine complexes synthesized at elevated

temperatures can be proposed as effective and promising inhibitor systems for the protection of equipment and pipelines against corrosion in the oil and gas industry.

Table 11.

Test Results of Preservation Fluids Prepared from Complexes of NPA Fraction I with Aliphatic Amines (Synthesized at Room Temperature) and T-30 Oil Distillate

№	Solution of Complexes in T-30 Oil Distillate	Total Amount of Inhibitor, %	Corrosion Protection Duration, days		
	Composition of Samples		In the “Г -4” Hydrochamber	In Seawater	In 0.001 % H_2SO_4 Solution
1	T-30 Oil Distillate	100	30	9	8
2	T-30 Oil Distillate + N-1	10	338	202	197
3	T-30 Oil Distillate + N-5	10	>276	205	202
4	T-30 Oil Distillate + N-9	10	329	178	175
5	T-30 Oil Distillate + N-13	10	313	192	188
6	T-30 Oil Distillate + N-17	10	>251	239	235

Table 12.

Test Results of Preservation Fluids Prepared from Complexes of NPA Fraction I with Aliphatic Amines (Synthesized at 40 °C) and T-30 Oil Distillate

№	Solution of Complexes in T-30 Oil Distillate	Total Amount of Inhibitor, %	Corrosion Protection Duration, days		
	Composition of Samples		In the “Г -4” Hydrochamber	In Seawater	In 0.001 % H_2SO_4 Solution
1	T-30 Oil Distillate	100	30	9	8
2	T-30 Oil Distillate + N-2	10	>338	210	208
3	T-30 Oil Distillate + N-6	10	>276	242	240
4	T-30 Oil Distillate + N-10	10	>337	270	262
5	T-30 Oil Distillate + N-14	10	>337	229	227
6	T-30 Oil Distillate + N-18	10	>250	192	187

Table 13.

Test Results of Preservation Fluids Prepared from Complexes of NPA Fraction I with Aliphatic Amines (Synthesized at 60 °C) and T-30 Oil Distillate

№	Solution of Complexes in T-30 Oil Distillate	Total Amount of Inhibitor, %	Corrosion Protection Duration, days		
	Composition of Samples		In the "Г -4" Hydrochamber	In Seawater	In 0.001 % H_2SO_4 Solution
1	T-30 Oil Distillate	100	30	9	8
2	T-30 Oil Distillate + N-3	10	>337	267	265
3	T-30 Oil Distillate + N-7	10	>276	190	187
4	T-30 Oil Distillate + N-11	10	>337	240	235
5	T-30 Oil Distillate + N-15	10	>337	265	260
6	T-30 Oil Distillate + N-19	10	>243	>239	>239

Tabel 14.

Test Results of Preservation Fluids Prepared from Complexes of NPA Fraction I with Aliphatic Amines (Synthesized at 80 °C) and T-30 Oil Distillate

№	Solution of Complexes in T-30 Oil Distillate	Total Amount of Inhibitor, %	Corrosion Protection Duration, days		
	Composition of Samples		In the "Г - 4" Hydrochamber	In Seawater	In 0.001 % H_2SO_4 Solution
1	T-30 Oil Distillate	100	30	9	8
Compositions Prepared from NPA Fraction I and Aliphatic Amines at 80 °C					
2	T-30 Oil Distillate + N-4	10	>311	260	263
3	T-30 Oil Distillate + N-8	10	>295	282	280
4	T-30 Oil Distillate + N-12	10	>311	255	247
5	T-30 Oil Distillate + N-16	10	>311	247	245
6	T-30 Oil Distillate + N-20	10	>248	246	246

The protective effect was found to vary primarily according to the structure of the nitrogen-containing component and its degree of hydrophobicity, and was recorded in the following order:

Octylamine > Dibutylamine > Heptylamine > Butylamine > Ethylenediamine

This order indicates that as the carbon chain length increases (particularly in octyl- and dibutylamines), the adsorption layer formed by the complexes on the metal surface becomes more stable, resulting in significantly prolonged protection times. Conversely, complexes obtained from shorter-chain amines or those containing two functional groups but lower hydrophobicity (such as ethylenediamine) exhibited weaker protective effects.

Statistical Optimization of the Results Obtained from the Application of Amine Compositions of NPA Fractions, Synthesized at Various Temperatures, as Additives to Preservation Fluids

To simultaneously evaluate the effects of oil fraction, amine type, and temperature on the inhibitory properties in several aggressive media, multivariate analysis of variance (MANOVA) was employed.

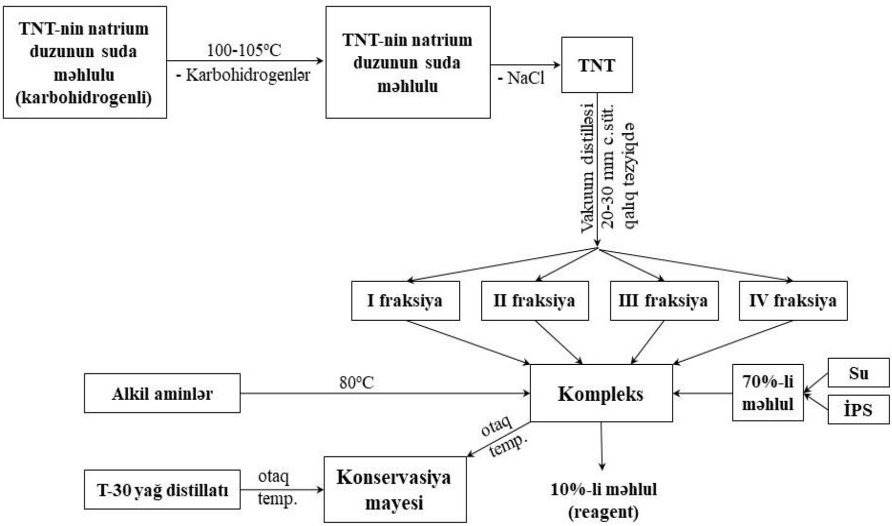
The MANOVA results demonstrated a highly significant overall model effect (Wilks' $\lambda = 0.043$, Pillai's trace = 0.957, $F = 264.34$, $p < 0.0001$), confirming that the selected factors collectively explained a significant proportion of the variability across all three corrosive media.

Examination of individual factors showed that the oil fraction (Wilks' $\lambda = 0.475$, $p = 0.0001$), amine type (Wilks' $\lambda = 0.158$, $p < 0.0001$), and temperature (Wilks' $\lambda = 0.465$, $p < 0.0001$) each had a significant effect on the properties of the inhibitors.

For optimization, a prediction network was constructed for the temperature range of 20–80 °C. The robustness of the modeling approach was assessed using several diagnostic procedures. Model fit was evaluated using the coefficient of determination (R^2), which demonstrated excellent predictive capability for the hydrochamber ($R^2 = 0.972$) and strong fit for seawater ($R^2 = 0.912$) and H_2SO_4 ($R^2 = 0.911$).

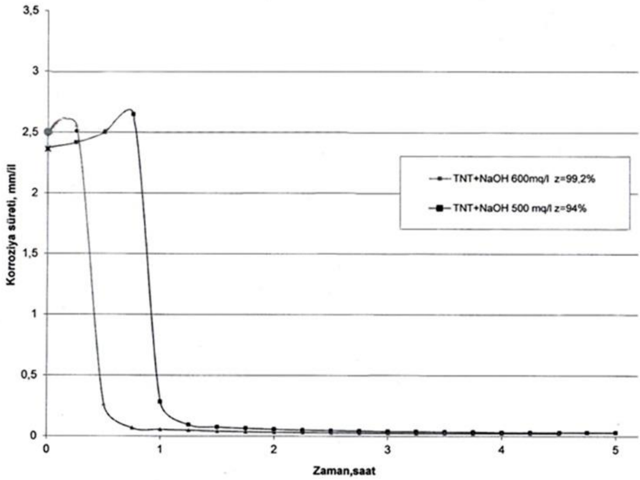
Principal Scheme for the Synthesis of NPA Complexes and the Production of Reagents and Preservation Fluids Derived from Them

The principal technological scheme for the production of reagents and preservation fluids is presented below (Scheme 4).
As seen, sodium chloride and a kerosene fraction are obtained as by-products in the process. The sodium chloride produced can be used as a component in the leather tanning industry or as an electrolyte in the electrolysis process for chlorine production. As noted above, the kerosene fraction can be used either as a solvent for dyes or as a fuel component.



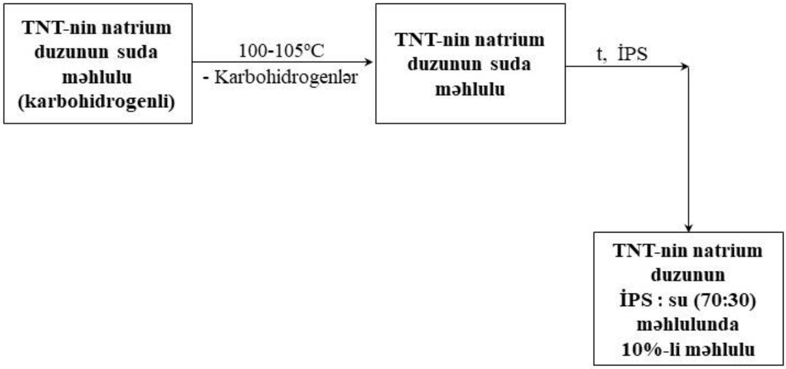
Scheme 4. Principal Scheme for the Production of Inhibitor-Bactericides and Preservation Fluids Derived from NPA.

Studies have established that the 10.0 % solution of the sodium salt of the total NPA fraction in 70.0 % aqueous IPA has a strong effect on the kinetics of CO_2 corrosion and significantly reduces the CO_2 corrosion process of a C1010 steel electrode in 1.0 % NaCl solution saturated with CO_2 at 50 °C. Specifically, the 10.0 % solution of the sodium salt of NPA, when introduced into the medium at 500 mg/L (equivalent to 50 mg/L of active substance) and 600 mg/L (equivalent to 60 mg/L of active substance), provides protection efficiencies of 94.0 % and 99.2 %, respectively (see Graph 1).



Graph 1. Effect of the Sodium Salt and Complex of NPA on the Kinetics of CO_2 Corrosion.

Based on the results obtained, it is possible to simplify the technological scheme for CO_2 corrosion protection and use the sodium salt of NPA—obtained as a by-product of oil refining—as a ready-to-use reagent without the need for additional reactants, except for IPA. In this case, the technological scheme will be as follows (Scheme 5).



Scheme 5. Principal Scheme for Obtaining a Reagent for CO_2 Corrosion Protection Based on NPA.

In this case, the use of hydrochloric acid is no longer required, hydrochloric acid is not produced as a by-product, and the use of economically expensive alkylamines is avoided.

RESULTS

1. The theoretical basis for obtaining high-quality, multifunctional inhibitor-bactericides and preservation fluids from the aqueous solution of the sodium salt of NPA—obtained as a by-product of the kerosene fraction of the Baku crude oil blend—was developed. The dependence of the protective efficiency of the resulting complexes and salts on the size of the NPA molecule, the length of the alkyl radical of the amines, the presence of primary or secondary amines, the presence or absence of alkyl radicals, and the synthesis temperature of the complexes was investigated [2,4,10].
2. Complexes synthesized from the fractions of NPA with $C_4H_9NH_2$, $(C_4H_9)_2NH$, $CH_2CH_2(NH_2)_2$, $C_7H_{15}NH_2$, $(C_5H_{11})_2NH$, and $C_8H_{17}NH_2$ were prepared as 10.0 % solutions in 70.0 % aqueous IPA, and their physicochemical properties were studied [2,3].
3. The effect of the solutions of alkylamine complexes of various NPA fractions on the kinetics of CO_2 corrosion was investigated. It was determined that, among the complexes of Fraction I, the butylamine complex is the most effective. Its 10.0 % solution, when added at 1000 mg/L to a medium of 1.0 % NaCl saturated with CO_2 at 50 °C, provided 98.8 % protection of a C1810 steel electrode against corrosion. The solutions of the butylamine, octylamine, diethylamine, and dibutylamine complexes and the sodium and potassium salts of NPA Fraction II exhibited high protective efficiency, providing 98.8 %, 99.0 %, 98.5 %, 94.0 %, 96.7 %, and 95.5 % protection, respectively, when added to the medium at 1000 mg/L [1,5,7].
4. The 10.0 % solutions of the butylamine and dibutylamine complexes of NPA Fraction III showed higher protection efficiencies when added at 1000 mg/L, providing 96.0 % and 94.5 % protection, respectively. The solutions of the complexes and salts obtained from Fraction IV exhibited protection efficiencies close to one another, ranging from 90.0 % to 99.0 % at a concentration of 1000 mg/L. An additional advantage of these solutions is that they provide sufficiently high protection even at

500 mg/L (in the range of 70.6–95.0 %).

A simplified technology was developed to produce a ready-to-use reagent directly from the sodium salt of the total NPA fraction, without performing any additional reactions—only by removing water (to eliminate the hydrocarbon ballast of the kerosene fraction) and adding an IPA:water mixture. This reagent, when introduced at 50 mg/L and 60 mg/L (calculated per active substance) into 1.0 % NaCl solution saturated with CO_2 at 50 °C, provided 94.0 % and 99.2 % protection, respectively, of a C1010 steel electrode against CO_2 corrosion [1,5,7].

5. The solutions of the synthesized complexes and salts were studied as inhibitors against H_2S corrosion. It was established that the solution of the octylamine complex of NPA Fraction I, at a concentration of 4000 mg/L, when introduced into a biphasic water:kerosene medium (9:1 by volume) containing 500 mg/L of H_2S, provided 98.2 % protection of a Steel-3 sample. Among the complexes of Fraction II, the butylamine, octylamine, dibutylamine, and dipentylamine complexes showed high efficiency, providing 98.0 %, 98.2 %, 95.0 %, and 99.8 % protection, respectively, when added at 4000 mg/L. The solution of the dipentylamine complex provided 84.1 % protection even at 1000 mg/L and 95.3 % protection at 2000 mg/L. The complexes of Fraction III showed weaker protection at the same concentrations, whereas the dipentylamine complex of Fraction IV was found to be more effective, providing 84.0 %, 89.0 %, 95.0 %, and 98.0 % protection at 1000, 2000, 3000, and 4000 mg/L, respectively [9,12].
6. The effects of the solutions of the alkylamine complexes obtained from various NPA fractions on the activity of sulfate-reducing bacteria (SRB) were investigated. It was found that, even at 15 mg/L, these solutions inhibited SRB activity by 99.0–100.0 %, practically eliminating H_2S from the medium. This finding is of great practical importance, as it contributes to reducing the frequency of oilfield equipment repairs, preventing accidents, and maintaining oil quality [6,8,9].
7. The possibility of creating preservation fluids that provide long-

term protection against atmospheric corrosion, based on alkylamine complexes of various NPA fractions and T-30 oil distillate, was demonstrated. It was established that certain complexes, when incorporated at 10.0 % into T-30 oil distillate, produced preservation fluids that protected Steel-3 samples for 337 days in a hydrochamber, 270 days in Caspian Sea water, and 262 days in 0.001 % H_2SO_4 solution [8].

8. A technology for obtaining multifunctional inhibitor-bactericides and preservation fluids based on NPA fractions was developed. The main stages of this technology are as follows:
   - Purification of the aqueous solution of the sodium salt of NPA from hydrocarbon ballast;
   - Treatment of the NPA salt solution with hydrochloric acid to obtain NPA; vacuum distillation and fractionation of NPA;
   - Preparation of amine complexes and salts of the NPA fractions;
   - Preparation of solutions of the complexes and salts in alcohol–water mixtures, or incorporation of the complexes into T-30 oil distillate to produce preservation fluids, depending on the intended application [11].

List of published scientific works on the topic of the dıssertatıon:

1. Alimadatli, N.Y. The influence of some salts and complexes of the fraction of natural petroleum acids obtained from the kerosene fraction of Baku oils on CO_2 corrosion kinetics // PPOR, – 2023. Vol. 24, No. 1, – p.147-153.

2. Alimadatli, N.Y. Summary of scientıfıc research conducted at academician Y.H. Mammadaliyev Institute of Petrochemical Processes in synthesizing and researching corrosion inhibitors and inhibitor-bactericides/ N.Y. Alimadatli, N.Sh. Rzayeva // PPOR, – 2023. Vol. 24, No. 2, – p.286-295.

3. Abbasov, V.M. Synthesis of complexes of oleic acid with

alkylamines and theoretical study of their structures/ V.M. Abbasov, N.Y.Alimadatli, R.E. Azizov, D.B.Aghamaliyeva, A.M. Mammadov // PPOR, – 2023. Vol. 24, No. 4, – p.831-842.

4. Abbasov, V.M., Azizov, R.E., Aghamaliyev, Z.Z., Aydinsoy, E.A., Alimadatli, N.Y. The Localızatıon of Oil Leaks in The Sea Using Satellite and Drone Images With Artificial Intelligence Models. // International Conference dedicated to the 60th anniversary of the establishment of the Department of Technology of organic substances and high-molecular compounds. "Modern problems of macromolecular compound technology". Proceedings of Azerbaijan High Technical Educational Institutions, – Baku, – 2024, – Vol.26, Special issue 2 (148), – p.421-431.

5. Əlimədətli, N.Y. Təbii üzvi turşuların alkil amin komplekslərinin alınma temperaturunun inhibitor və bakterisid effektinə təsiri // Akademik Məhərrəm Əli oğlu Məmmədyarovun 100 illik yubileyinə həsr olunmuş "Neft kimyasının və yağların texnologiyasının müasir problemləri" adlı Beynəlxalq elmi konfrans, Bakı, – 26-27 sentyabr, – 2024, – s.164.

6. Abbasov, V.M., Ağamalıyeva, D.B., Qurbanova, F.C., Əlimədətli, N.Y. Günəbaxan yağ turşusunun amidoamininin pentilyodid kompleksinin bakterisid xassələrinin tədqiqi // Akademik Məhərrəm Əli oğlu Məmmədyarovun 100 illik yubileyinə həsr olunmuş "Neft kimyasının və yağların texnologiyasının müasir problemləri" adlı Beynəlxalq elmi konfrans, –Bakı, 26-27 sentyabr, – 2024, – s.231-232.

7. Əlimədətli, N. Azotlu üzvi komplekslərin inhibitor xassələrinə komplekslərin alınma temperaturlarının təsiri // Akademik Soltan Cəfər oğlu Mehdiyevin 110 illik yubileyinə həsr olunmuş "Monomerlər və neft kimyasının müasir problemləri" adlı Beynəlxalq elmi konfrans, – Bakı, – 19-20 dekabr, – 2024, – s.278.

8. Abbasov, V., Aghamalıyeva, D., Aghamalıyev, Z., Aydınsoy, E., Alimadatli, N. Antibacterial evaluation of stearic acid-derived molecules for water purification: a case study on Caspian seashore near Sumgait // Third Internatıonal Bilateral Workshop on Natural Science Between Dokuz Eylul University And Azerbaijan National Academy of Sciences. – 5 December, – 2024, – p.17.

9. Abbasov, V.M. Effect of complexes of dıfferent fractions of natural petroleum acids with different alkyl amines on the vital activity of sulphate-reducing bacteria / V.M.Abbasov, N.Y.Almadatli, R.E.Azizov, N.Sh.Rzayeva, D.B.Aghamaliyeva, S.F.Ahmadbayova, A.F.Abbasova // PPOR, – 2025. Vol. 26, No. 2, – p.555-563.

10. Alimadatli, N.Y. Summary of research on the development of multifunctional corrosion protection agents at the academician Y.H.Mammadaliyev Institute of Petrochemical Processes of the Ministry of Science and Education of the Republic of Azerbaijan // PPOR, – 2025. Vol. 26, No. 2, – p.534-543.

11. Alimadatli, N.Y. Summary of research on the development reagents based on nitrogen-containing organic compounds for the oil and gas extraction and processing industry at the Instıtute of Petrochemical Processes (IPCP) // PPOR, – 2025. Vol. 26, No. 3, – p.639-656.

12. Аббасов, В.М. Изучение ингибиторных свойств алкил- и диалкиламинных комплексов 1-ой фракции ПНК против коррозии H_2S в кислой среде / В.М.Аббасов, Н.Ю.Алимадатли, Н.Ш.Рзаева, Д.Б.Агамалиева, И.Г.Аюбов, С.М.Аббасзаде, С.Б.Асадова // Вестник КНИИ РАН, – 2025. № 3, с.1-10.

The defense will be held on «31» October 2025 at 10^{00} at the meeting of the Dissertation council ED 1.17 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at the Institute of Petrochemical Processes of Azerbaijan Republic MSE

Address: AZ 1025, Baku., Khojaly ave., 30

Dissertation is accessible at the Institute of Petrochemical Processes of Azerbaijan MSE Library

Electronic versions of dissertation and its abstract are available on the official website of the Institute of Petrochemical Processes of Azerbaijan Republic MSE

Abstract was sent to required adresses on: «30» September 2025.

Signed for print: 29.09.2025

Paper format: A5

Volume: 38856

Number of hard copies: 20 copies