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[1]South Kazakhstan Pedagogical University named after O. Zhanibekov,
Shymkent, Kazakhstan;
[2]International Kazakh-Turkish University named after H.A.Yassawi,
Turkestan, Kazakhstan.
E-mail: zhylysbayeva.akkongyr@okmpu.kz

POSSIBILITIES AND DIFFICULTIES IN APPLYING ARTIFICIAL INTELLIGENCE FOR LEARNING INORGANIC CHEMISTRY

Bauyrzhan Laura — PhD student, South Kazakhstan Pedagogical University named after O. Zhanibekov, Shymkent, Kazakhstan,
E-mail: laurarahymjan@gmail.com, https://orcid.org/0009-0006-8572-5482;
Zhylysbayeva Akkongyr — candidate of chemical sciences; associate professor, Director of the Postgraduate Education Institute of South Kazakhstan Pedagogical University named after O. Zhanibekov, Shymkent, Kazakhstan,
E-mail: zhylysbayeva.akkongyr@okmpu.kz , https://orcid.org/0000-0001-9114-7582;
Zhylysbayeva Gulkhan — candidate of technical sciences; associate professor, International Kazakh-Turkish University named after K.A. Yassawi, Turkestan, Kazakhstan,
E-mail: gulkhan.zhylysbayeva@ayu.edu.kz , https://orcid.org/0000-0002-9800-3896.

Abstract. The article discusses the opportunities and challenges of using generative artificial intelligence (AI) in teaching chemistry in higher education institutions. Among modern AI technologies, ChatGPT is one of the most discussed and widely used tools to help students master complex teaching material. The aim of the study is to analyze the main difficulties encountered by the ChatGPT model in solving chemistry problems and to identify the peculiarities of using AI in the process of professional training of future chemistry teachers. To collect empirical data, a study was conducted among students in the “Chemistry teacher training” educational program at the South Kazakhstan Pedagogical University named after O. Zhanibekov. A survey was carried out to find out how actively students use ChatGPT in chemistry classes and for what purposes, and the results were subjected to statistical analysis. The possibilities of generative AI in transferring conceptual knowledge in chemistry were also investigated. The ChatGPT models were given chemistry problems to solve, organized into three levels of difficulty and covering various topics in inorganic chemistry. According to the study results,

the chat-bot provided the correct answer to 77.77% of the questions asked, was unable to provide a completely correct answer to 5.55%, and gave an incorrect answer to the remaining 16.66%. The study found that ChatGPT was unable to correctly use chemical terminology when solving highly complex problems, made errors in balancing chemical equations and stoichiometric calculations, and was unable to fully grasp complex conceptions. Therefore, when integrating such models into pedagogical practice, we recommend taking their limitations into account, provide pedagogical support and use them as an auxiliary tool rather than the main means of teaching.

Keywords: generative artificial intelligence, ChatGPT, chemistry teaching, professional teacher training, chemical tasks, AI in education, difficulties in applying AI

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© Бауыржан Л.Н.[1], Жылысбаева А.Н.[1]*, Жылысбаева Г.Н.[2], 2026.
[1] Ө. Жәнібеков атындағы Оңтүстік Қазақстан педагогикалық университеті, Шымкент, Қазақстан;
[2]Қ.А. Ясауи атындағы халықаралық қазақ-түрік университеті, Түркістан, Қазақстан.
E-mail: zhylysbayeva.akkonyr@okmpu.kz

БЕЙОРГАНИКАЛЫҚ ХИМИЯНЫ ОҚЫТУДА ЖАСАНДЫ ИНТЕЛЛЕКТТІ ҚОЛДАНУДЫҢ МҮМКІНДІКТЕРІ МЕН ҚИЫНШЫЛЫҚТАРЫ

Бауыржан Лаура — PhD докторант, Өзбекәлі Жәнібеков атындағы Оңтүстік Қазақстан педагогикалық университеті, Шымкент, Қазақстан,
E-mail: laurarahymjan@gmail.com, https://orcid.org/0009-0006-8572-5482;
Жылысбаева Аққоңыр — химия ғылымдарының кандидаты, доцент, жоғары оқу орнынан кейінгі білім беру институтының директоры, Өзбекәлі Жәнібеков атындағы Оңтүстік Қазақстан педагогикалық университеті Шымкент, Қазақстан,
E-mail: zhylysbayeva.akkonyr@okmpu.kz, https://orcid.org/0000-0001-9114-7582;
Жылысбаева Гульхан — техника ғылымдарының кандидаты, доцент, Қожа Ахмет Ясауи атындағы Халықаралық қазақ-түрік университеті, Түркістан, Қазақстан,
E-mail: gulkhan.zhylysbayeva@ayu.edu.kz, https://orcid.org/0000-0002-9800-3896.

Аннотация. Мақалада жоғарғы оқу орындарында химияны оқыту кезінде генеративті жасанды интеллектті (ЖИ) пайдалану мүмкіндіктері мен мәселелері қаралды. Қазіргі заманғы жасанды интеллект технологияларының арасында ChatGPT студенттерге күрделі оқу материалдарын меңгеруге көмектесетін ең көп талқыланатын және кеңінен пайдаланылатын

құралдардың бірі болып табылады. Зерттеудің мақсаты – химия есептерін шешу кезінде ChatGPT моделі кездесетін негізгі қиындықтарды талдау және болашақ химия мұғалімдерін кәсіби даярлау процесінде ЖИ пайдалану ерекшеліктерін анықтау. Эмпирикалық деректерді жинау үшін Ө. Жәнібеков атындағы Оңтүстік Қазақстан педагогикалық университетінің «химия мұғалімдерін даярлайтын» білім беру бағдарламасының студенттері арасында зерттеу жүргізілді. Білім алушылардың химия сабағы барысында ChatGPT-ді қолдану аясын және қандай мақсатта қолданатынын білу мақсатында сауалнама алынды және оның нәтижелері статистикалық талдаудан өтті. Сондай-ақ, мақалада химиядағы тұжырымдамалық білімді беру кезінде генеративтік ЖИ мүмкіндіктері зерттелді. ChatGPT моделіне бейорганикалық химияның әртүрлі тақырыптарына байланысты күрделілігі бойынша үш деңгейге бөлінген химиялық есептерді шешу бойынша міндеттер қойылды. Зерттеу нәтижесі бойынша берілген есептердің 77.77% чат-бот дұрыс жауап берді, 5.55% толық дұрыс жауап бере алмады, ал қалған 16.66% қате жауап берді. Алынған нәтижелер бойынша ChatGPT-дің неғұрлым жоғары күрделілік деңгейдегі есептерді шешуде химиялық терминдерді дұрыс қолданбау, реакция теңдеулері мен стехиометриялық есептеулерде қателіктер және күрделі ұғымдарды толық меңгере алмағандығы анықталды. Сондықтан мұндай үлгілерді педагогикалық практикаға кіріктіру кезінде олардың шектеулерін ескеру, педагогикалық қолдау көрсету және оларды оқытудың негізгі құралы емес, көмекші құрал ретінде пайдалану қажеттігін ұсынамыз.

Түйін сөздер: генеративті жасанды интеллект, ChatGPT, химияны оқыту, мұғалімдерді кәсіби даярлау, химиялық есептер, білім берудегі ЖИ, ЖИ қолданудағы қиындықтар

© Бауыржан Л.Н.[1], Жылысбаева А.Н.[1*], Жылысбаева Г.Н. [2], 2026.
[1]Южно-Казахстанский педагогический университет имени Ө. Жәнібеков, Шымкент, Казахстан;
[2]Международный казахско-турецкий университет университет имени Х.А. Ясауи, Туркестан, Казахстан.
E-mail: zhylysbayeva.akkonyr@okmpu.kz

ПЕРСПЕКТИВЫ И ТРУДНОСТИ ИСПОЛЬЗОВАНИЯ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА В ИЗУЧЕНИИ НЕОРГАНИЧЕСКОЙ ХИМИИ

Бауыржан Лаура — PhD докторант, Южно-Казахстанкий педагогический университет имени Өзбекәлі Жәнібеков, Шымкент, Казахстан,
E-mail: laurarahymjan@gmail.com, https://orcid.org/0009-0006-8572-5482;
Жылысбаева Акконыр — кандидат химических наук, доцент, директор института послевузовского образования Южно-Казахстанского педагогического университета имени Өзбекәлі Жәнібеков, Шымкент, Казахстан,

E-mail: zhylysbayeva.akkonyr@okmpu.kz, https://orcid.org/0000-0001-9114-7582;
Жылысбаева Гульхан — кандидат технических наук, доцент, Международный казахско-турецкий университет имени Ходжи Ахмеда Ясави, Туркестан, Казахстан,
E-mail: gulkhan.zhylysbayeva@ayu.edu.kz, https://orcid.org/0000-0002-9800-3896.

Аннотация. В статье рассматриваются возможности и проблемы применения генеративного искусственного интеллекта (ИИ) в преподавании химии в организациях высшего образования. Средисовременных ИИ-технологий ChatGPT является одним из наиболее обсуждаемых и широко используемых инструментов, способных оказывать поддержку студентам при освоении сложного учебного материала. Цель исследования заключается в анализе основных затруднений, возникающих при использовании модели ChatGPT для решения задач по химии, а также в выявлении особенностей применения ИИ в процессе профессиональной подготовки будущих учителей химии. Для сбора эмпирических данных было проведено исследование с участием студентов образовательной программы «Подготовка учителей химии» Южно-Казахстанского педагогического университета имени Өзбекәлі Жәнібекова. Опрос был направлен на выявление интенсивности и целей использования ChatGPT студентами на занятиях по химии, а полученные данные были обработаны методами статистического анализа. Кроме того, исследованы возможности генеративного ИИ в представлении и объяснении концептуальных знаний по химии. Модели ChatGPT были предложены задачи по различным темам неорганической химии, распределенные по трем уровням сложности. Согласно результатам исследования, чат-бот дал правильные ответы на 77,77% заданий, частично правильные - на 5,55%, неправильные - на 16,66%. Анализ полученных результатов показал, что при решении задач повышенной сложности ChatGPT допускал неточности в использовании химической терминологии, ошибки при составлении уравнений химических реакций и выполнении стехиометрических расчетов, а также демонстрировал ограниченную способность корректно интерпретировать сложные химические концепции. В связи с этим при интеграции подобных моделей в педагогическую практику целесообразно учитывать их ограничения, обеспечивать педагогическое сопровождение и использовать генеративный искусственный интеллект преимущественно в качестве вспомогательного, а не основного средства обучения.

Ключевые слова: генеративный искусственный интеллект, ChatGPT, преподавание химии, профессиональная подготовка учителей, химические задачи, ИИ в образовании, трудности применения ИИ

Introduction. Modern trends in the digitalization of education contribute to the active integration of artificial intelligence (AI) technologies into the learning process. One of the most in-demand tools today is ChatGPT – a language model capable of generating text, answering questions, summarizing content, and

performing various tasks related to information processing. In the context of the rapid development of students' digital skills and competencies, the role of such technologies in educational environments has become especially relevant. In this regard, president Kassym-Jomart Tokayev emphasized in the 2023-2029 Concept for the Development of Higher Education and Science that the use of AI approaches in the educational process enables students to acquire theoretical knowledge and practical skills more effectively (message of the head of the Republic of Kazakhstan, 2023). AI offers many opportunities in education, especially in the study of chemistry. To be precise, it makes it possible to understand difficult scientific concepts, helps analyze information, and facilitates the process of learning chemistry. In this context, the use of language models such as ChatGPT opens new opportunities for personalized learning, support in academic writing, development of research competencies, and quick access to reference materials. Nowadays AI can serve as an assistant capable of adapting to the learner's level of preparedness, explaining complex concepts, helping structure scientific texts, and assisting in the preparation of laboratory reports. Therefore, exploring the role of AI tools as an essential component of the digital learning environment is of particular importance for enhancing the effectiveness of chemistry education and fostering students' academic autonomy.

Literature review. Artificial intelligence (AI), particularly the widely recognized ChatGPT, has attracted increasing attention from researchers due to its vast potential in the field of education (Gocen and Aydemir, 2020). Several studies have demonstrated ChatGPT's ability to tackle challenges across various academic disciplines (Dai et al., 2023), raising the question of whether the model can truly comprehend and articulate complex concepts and interconnections in a clear and multifaceted way.

In a recent study, West (2023) compared the effectiveness of ChatGPT 3.5 and ChatGPT 4.0 in the context of physics education. The author noted that while ChatGPT 3.5 occasionally mimicked the reasoning of an experienced physicist, it often lacked consistency, leading to discrepancies and gaps across different topics. In contrast, ChatCPT 4.0 displayed several aspects of genuine "understanding" due to its use of metaphorical thinking and integration of multiple perspectives. Nevertheless, the study concluded that even ChatGPT 4.0 does not yet offer a comprehensive or profound understanding of physics (West, 2023).

Güçen and Aydemir (2020) highlighted several advantages of AI in education, including its ability to personalize the learning process and make informed decisions by leveraging large databases. Dwivedi and colleagues (2023) further demonstrated that AI can engage in structured reasoning based on learning outcomes due to its capacity to predict and adapt to changes. According to the research of Dai et al., (2023), ChatGPT can serve multiple roles in classroom settings, supporting the educational process at the university level while upholding academic integrity. Its applications include creative writing, problem-solving, scientific and group projects, as well as classroom discussions. Additionally, a

number of recent studies (Aljanbi et al., 2023; Firat, 2023) have underscored ChatGPT's versatility in educational contexts, highlighting its use in academic writing, search support, coding assistance, vulnerability detection, social media analysis, and as an autonomous agent.

AI has numerous applications in the field of education, including intelligent tutoring systems, technology-based learning platforms, and automated assessment tools (Adiguzel et al., 2023). Research has shown that ChatGPT enhances students' engagement and motivation in the learning process (Munoz et al., 2023). In the study by Orru and colleagues (Orru et al., 2023; Cracolice et al., 2008; Roth, 2013), ChatGPT demonstrated its problem-solving capabilities by successfully completing experimental tasks and complex problem sets, ranking in the top 5% of response combinations. In addition, domestic researchers such as Abdikayumova N.A. (2025) and her collaborators (Abdikayumova et al., 2025) have explored the potential and advantages of artificial intelligence and addressed the issues surrounding its integration into the higher education system. This means that AI is not only relevant abroad, but also in our educational system in Kazakhstan.

Generative artificial intelligence (GAI) has been identified in several studies (Cooper, 2023; Leon and Vidhani, 2023) as a helpful tool for assisting students in scientific disciplines, particularly chemistry. However, to be effectively applied in educational settings, AI must possess an understanding of scientific concepts and their interrelations – especially in the context of conceptual knowledge in chemistry. Previous studies have examined various aspects of conceptual understanding in chemistry. Furthermore, emerging research suggests that AI technologies, including ChatGPT, can be integrated into various branches of chemistry – such as organic chemistry, experimental practices, and problem-solving tasks (Yildirim and Akcan, 2024).

The purpose of the research: to investigate the challenges faced by ChatGPT 4.0 in solving chemistry-related problems and to examine how students in the fields of chemistry teacher education utilize AI technologies in their learning.

The research questions:

1. How will the ChatGPT solve chemical problems at three levels in inorganic chemistry?
2. How do students use AI technologies to learn chemistry?

The research hypothesis: students specializing in chemistry teacher education can effectively use ChatGPT 4.0 as an auxiliary tool in solving problems in inorganic chemistry. However, the model demonstrates limitations when dealing with tasks that require conceptual understanding, which may be attributed to its incomplete grasp of domain-specific logic.

Materials and methods. *Research design.* The present study employed a mixed-methods approach, incorporating both quantitative analysis (to evaluate the accuracy of ChatGPT's responses to chemistry problems) and qualitative analysis (to assess the logical consistency and completeness of the explanations through expert review). This methodological combination allowed for a comprehensive

evaluation of ChatGPT's effectiveness in solving chemistry problems and providing theoretical justification.

Our research focused on assessing ChatGPT's problem-solving capabilities in the field of chemistry, particularly within the domain of inorganic chemistry. The problems covered the topics of "Gases and gas laws", "Solutions", and "Redox reactions".

To ensure analysis of the collected data, a quantitative method was also applied. A survey was conducted to determine the scope and purpose of ChatGPT usage by students during chemistry lessons. The questionnaire aimed to identify students' experience with using AI in educational contexts and was designed using a Likert scale.

Research participants. Participants were selected through a convenience sampling strategy among students enrolled in the "Chemistry teacher training" educational program at the O. Zhanibekov South Kazakhstan Pedagogical University. This sampling method allowed the researchers to access respondents easily and obtain useful insights relevant to the study objectives and hypotheses. In total, 53 students from the aforementioned institution participated in the survey.

Research instrument. The survey results were analyzed based on the participants' year of study and their educational program. The questionnaire consisted of 12 questions, including both single-choice and multiple-choice questions. It was structured around three core domains: students' experience with AI tools, their level of trust in AI-generated responses, and the perceived impact of AI on the learning process. The survey was created and administered anonymously using the Google Forms platform.

Data collection. The research data were collected using a questionnaire titled "Use of AI in solving chemistry problems". Surveys are considered a reliable method of data collection, as they offer highly structured, objective, and precise information suitable for through analysis. The questionnaire was distributed to all students enrolled in the "Chemistry teacher training" program via Google Forms. It remained accessible online for two weeks. All responses were processed confidentially, and participation in the study was entirely voluntary.

The investigation into the capacity of generative AI to handle conceptual chemistry knowledge was conducted within the scope of the "Inorganic chemistry" course. ChatGPT was assigned a series of problem-solving tasks related to inorganic chemistry. The problem set included tasks of varying complexity, categorized into three levels, and was derived from a recognized educational resource (Zhylysbayeva et., al, 2023). The specific task set provided to ChatGPT is presented in Table 1.

Table 1 — Problems solved using generative artificial intelligence (GAI)

Gases and gas laws	
Easy level	The pressure of 5 liters of gas at an unknown temperature was 103.5 kPa. If the volume of the gas is reduced to 5.8 liters without changing the temperature, what will be the new pressure of the gas?
	At a temperature of 32°C, the volume of a gas was 800 mL. if the temperature is increased to 62°C while keeping the pressure constant, what will be the new volume of the gas?

Intermediate level	At a pressure of 100 kPa, 2 liters of oxygen and 4 liters of sulfur (IV) oxide were mixed. The total volume of the mixture was 6 liters. Determine the partial pressures of the gases in the mixtures.
	A mixture was formed from 3 L of CO_2, 4 L of O_2, and 6 L of N_2. Before mixing, the pressures of these three gases were 96, 108, and 90.6 kPa, respectively. The total volume of the mixture is 10 liters. Calculate the total pressure of the gas mixture.
Advanced level	Three identical containers (same volume and mass) are filled with different gases under the same conditions. The first container filled with hydrogen has a mass of 24.8 g. the second container filled with oxygen has a mass of 36.8 g. The third container is filled with a mixture consisting of 40% nitrogen by volume and an unknown gas; the total mass of the third container is 33.28 g. Determine the identity of the unknown gas.
	To 100 g of a 13.8% sodium nitrate solution, 10.7 g of ammonium chloride was added. Upon heating the mixture, 4.48 L of gas (at STP) was released. After adding silver nitrate to the remaining solution, 11.7 g of a white crystalline precipitate was obtained. The released gas was combined with the gas produced by reacting 39 g of zinc with hydrochloric acid. This gas mixture was then passed first over a platinum catalyst at 350°C and subsequently through an aqueous solution of sulfuric acid. During this process, the gas volume decreased, and to neutralize the remaining solution, 41.67 L of 22.4% KOH solution (ρ=1.2 g/cm^3) was required. Write the equations for the reactions that occurred. Determine the composition (in volume %) of the gas mixture after passing through the platinum catalyst.
Solutions	
Easy level	In 250 g of water, 50 g of $FesO_4$*$7H_2O$ crystal hydrate was dissolved. Calculate the mass fractions of the crystal hydrate and the anhydrous iron (II) sulfate ($FeSO_4$) in the solution.
	To prepare 1 liter of an 8% (w/w) solution of anhydrous salt, determine the required masses of water and copper (II) sulfate pentahydrate ($CuSO_4$*$5H_2O$). Given the density of the 8% $CuSO_4$ solution is 1.084 g/mL.
Intermediate level	How many milliliters of 36% hydrochloric acid (HCl) with a density of 1.183 g/mL are required to prepare 2 liters of 1 M HCl solution?
	How many milliliters of 96% sulfuric acid (H_2SO_4) with a density of 1.84 g/mL are needed to prepare 1 liters of 2N H_2SO_4 solution?
Advanced level	A 15% H_2SO_4 solution has a density of 1.10 g/mL. Determine the following concentrations for the solution: molality, normality, molarity.
	A 15% H_2SO_4 solution (total mass=350 g) must be prepared by mixing two sulfuric acid solutions: one with 7.5% concentration and the other with 60% concentration. Calculate the mass of each solution required for the mixture.
Redox reactions	
Easy level	Complete the oxidation reactions of hydrogen sulfide using the half-reaction method, based on the reaction scheme with chlorine water: $H_2S+Cl_2+H_2O \rightarrow H_2SO_4+HCl$
	Using the Half-Reaction method, construct the complete redox equations for the following reactions: a) $FeSO_4+KMnO_4+H_2SO_4 \rightarrow$ b) $KClO_3+HCl \rightarrow$ c) $Si+NaOH+H_2O \rightarrow$

Intermediate level	150 mL of a 6% potassium permanganate ($KMnO_4$) solution with a density of 1.04 g/mL reacts with potassium iodide (KI) solution in the presence of sulfuric acid. Calculate the mass of iodine (I_2) that is liberated in the reaction.
	To a 500 g hydrochloric acid solution, 15.8 g of potassium permanganate ($KMnO_4$) with a mass fraction of 35% is added. Determine the volume of the gas produced at standard conditions (STP), and calculate the number of moles in the final solution.
Advanced level	During electrolysis of a salt of a trivalent metal, a current of 3 A was passed for 2 hours. As a result, 4.18 g of metal was deposited on the cathode. Determine the identity of the metal. Also, write the equations for the cathode and anode processes, the overall equation for electrolysis of the molten salt, and the overall reaction in aqueous solution with a platinum anode and sodium carbonate present.
	A galvanic cell is constructed with zinc metal immersed in a 0.1 M zinc nitrate solution and lead metal immersed in a 0.02 M lead nitrate solution. Calculate the electromotive force (EMF) of the cell, write the equations for the electrode reactions, and draw the schematic diagram of the electrochemical cell.

Note: compiled by the authors.

In this study, a total of 18 chemistry problems from the "Inorganic chemistry" course were analyzed, covering the topics of "Gases and gas laws", "Solutions", and "Redox reactions". The problem set consisted of 6 tasks at the easy level, 6 at the intermediate level, and 6 at the advanced level. All the tasks were presented in Kazakh language (Zhylysbayeva et., al, 2023).

The quality of ChatGPT's a responses was evaluated using the following criteria:

- Accuracy of the response – does the solution correspond to the correct result?
- Completeness of explanation – are sufficient justifications and examples provided in the answer?
- Correct use of terminology – does the chatbot employ scientifically accurate definitions and symbols?
- Logical consistency of reasoning – are there any errors in the step-by-step problem-solving process?
- Identification of potential limitations and errors – are there cases in which ChatGPT provides incorrect or incomplete responses?

*Data analysis***.** To assess the reliability of the instrument, Cronbach's Alpha coefficient was calculated. The survey data were analyzed using SPSS to perform normality testing, reliability analysis, and descriptive analysis.

Results. In this study, we examined how ChatGPT solves chemistry problems of varying complexity, using the topic "Gases and gas laws" as an illustrative example.

Table 2 presents a sample chemistry problem at the easy level from the topic "Gases and gas laws", along with the correct answer and the response generated by the AI model (OpenAI, 2025). ChatGPT successfully solved the Level 1 problem related to gas laws. The model applied fundamental principles such as Boyle's Law accurately, providing a correct and coherent solution. The response was both precise and logically structured, confirming the model's ability to handle low-complexity chemistry tasks effectively.

Table 2 — An “easy-level” problem on the topic “Gases and gas laws”

Problem 1 – Easy level
Given The pressure of 5 liters of gas at an unknown temperature was 103.5 kPa. If the volume of the gas is reduced to 5.8 liters without changing the temperature, what will be the new pressure of the gas? ***Answer:*** 89.22 kPa
ChatGPT 4.0 **Given:** Initial pressure: P_1=103.5 kPa Initial volume: V_1=5.0 L Final volume: V_2=5.8 L Temperature is constant **Find:** final pressure P_2-? Solution using Boyle’s Law: $P_1*V_1=P_2*V_2$ -> $P_2=P_1*V_1/V_2$=103.5*5.0/5.8=89.22 kPa **Answer:** The final pressure is approximately 89.22 kPa

Note: compiled by the authors.

Table 3 presents a sample chemistry problem at the intermediate level on the topic “Gases and gas laws”, along with the response generated by the AI model. Using Dalton’s Law of Partial Pressure, ChatGPT correctly solved a moderately complex problem related to gases. The model accurately applied the principle that the total pressure of a gas mixture is equal to the sum of the partial pressures of its individual components. The answer was precise and aligned with theoretical expectations, demonstrating the model’s ability to effectively handle tasks that require the application of specific gas laws.

Table 3 — An “intermediate-level” problem on the topic “Gases and gas laws”

Problem 1 – Intermediate level
Given At a pressure of 100 kPa, 2 liters of oxygen and 4 liters of sulfur (IV) oxide were mixed. The total volume of the mixture was 6 liters. Determine the partial pressures of the gases in the mixtures. ***Answer:*** P_{O2}=33.3 kPa, P_{SO2}=66.7 kPa
ChatGPT 4.0 **Given:** Total pressure: P_{total}=100 kPa Volume of O_2=2 L, volume of SO_2=4 L Total volume = 6L **Find:** partial pressures P_{O2} and P_{SO2}-? Solution using Dalton’s law and volume ratios: $P_{O2}= P_{total}*V_{O2}/V_{total}$=100*2/6=33.33 kPa P_{SO2}=100*4/6=66.67 kPa **Answer:** P_{O2}= 33.33 kPa, P_{SO2}=66.67 kPa

Note: compiled by the authors.

Table 4 presents an advanced-level chemistry problem on the topic “Gases and gas laws”, along with the response generated by the AI model. In this case, ChatGPT made an error while attempting to identify the gas present in a third container, which held nitrogen and an unknown gas. While the model correctly

analyzed the first two gases – hydrogen and oxygen – it misinterpreted the data related to the third gas. As a result, the final outcome was incorrect. Despite correctly applying fundamental theoretical principles, the model made a mistake during the final stage of identifying the gas mixture composition. This highlights the need for more careful analysis in the concluding steps of problem-solving, particularly when interpreting data involving gas mixtures.

Table 4 —An "advanced-level" problem on the topic "Gases and gas laws"

Problem 1 –Advanced level
Given   Three identical containers (same volume and mass) are filled with different gases under the same conditions. The first container filled with hydrogen has a mass of 24.8 g. the second container filled with oxygen has a mass of 36.8 g. The third container is filled with a mixture consisting of 40% nitrogen by volume and an unknown gas; the total mass of the third container is 33.28 g. Determine the identity of the unknown gas.   ***Answer:*** The unknown gas is - neon
ChatGPT 4.0   **Given:**   All containers have equal volume -> under the same temperature and pressure, the number of moles of gas will also be the same.   **First container filled with hydrogen:**   -Total mass: 24.8 g   -Molar mass of hydrogen: M_{H2}=2 g/mol   -Number of moles: n=24.8/2=12.4 mol   **Second container filled with oxygen:**   -Total mass: 36.8 g   -Molar mass of oxygen: M_{O2}=32 g/mol   -Number of moles: n=36.8/32=1.15 mol   However, we know that all containers must have the same number of moles (as calculated from the hydrogen container: 12.4 mol). Therefore, other gases must also be present in the amount of 12.4 mol.   **2. Analysis of the third container:**   -Total mass: 33.28 g   -Gas mixture: 40% nitrogen (N_2) and an unknown gas (X)   -Molar mass of nitrogen: M_{N2}=28 g/mol   **Calculate nitrogen mass:**   Since nitrogen makes up 40% of the gas mixture by mass: m_{N2}=33.28*0.4=13.31 g   **Moles of nitrogen:** n_{N2}=13.31/28=0.475 mol   Since total moles = 12.4 mol, the number of moles of the unknown gas is: nX=12.4-0.475=11.925 mol   **Mass of the unknown gas:** mX=33.28-13.31=19.97 g   **Molar mass of the unknown gas:** MX=19.97/11.925≈1.68 g/mol   **3. Identifying the unknown gas:**   A gas with a molar mass of approximately 1.68 g/mol could potentially be helium (He) or neon (Ne).   -Molar mass of helium: 4 g/mol   -Molar mass of neon: 20 g/mol   These values do not precisely match the calculated 1.68 g/mol. However, considering possible experiment or calculation inaccuracies, the most likely identity of the gas is helium (He).   **Conclusion:** The unknown gas is helium (He).

Note: compiled by the authors.

Unfortunately, in this case, the generative model GPT-4.0 was unable to solve the high-level problem correctly. In conclusion, although the model demonstrated appropriate use of theoretical knowledge and correctly addressed many intermediate steps of the task, an error in the final stage led to an incorrect solution. This emphasizes the importance of careful and thorough attention throughout all stages of solving advanced-level problems. The correct solution to the problem is provided in Table 5.

Table 5 — The correct solution to the "advanced-level" problem on the topic "Gases and gas laws"

Problem 1 –Advanced level
Three identical containers (same volume and mass) are filled with different gases under the same conditions. The first container filled with hydrogen has a mass of 24.8 g. the second container filled with oxygen has a mass of 36.8 g. The third container is filled with a mixture consisting of 40% nitrogen by volume and an unknown gas; the total mass of the third container is 33.28 g. Determine the identity of the unknown gas. ***Answer:*** The unknown gas is - neon
Solution process from the book: Let us denote the mass of the empty container as m_c, and the molar mass of the unknown gas as X. Then we can write: $\nu(H_2)*2+ m_c=24.8$ (1) $\nu(O_2)*32+ m_c=36.8$ (2) Since the number of moles of the gases is equal (same volume, pressure, and temperature), we solve equations (1) and (2): $m_c=24.0$ g, $\nu(H_2)=\nu(O_2)=0.4$ mol We find the total mass of the gas mixture in the third container by subtracting the container's mass: 33.28-24.0=9.28 g In this container, the amount of nitrogen is: $\nu(N_2)= \nu$ (mixture)*0.4=0.16 mol We determine the molar mass of the unknown gas using the equation: 9.28=0.16*28+(0.4-0.16)*X Solving for X: X=28 g/mol Conclusion: The unknown gas is neon (Ne).

Note: compiled by the authors.

In addition, ChatGPT provided correct responses to all three levels of problems related to the topic "Solutions". However, it was unable to fully solve the easy-level problem on the topic "Redox Reactions" and failed to correctly solve the advances-level problem, although it performed accurately on the intermediate-level tasks. This means that the ChatGPT does not always give us the correct answers.

As a result of the second research question, a survey was conducted to identify the use of ChatGPT in chemistry lessons. It also sought to gather students' opinions on the use of ChatGPT in chemistry education and recommendations for their future application.

When asked whether they use artificial intelligence technologies to solve chemical problems and equations, 51 students (96%) responded "Yes", and only 2 students (4%) responded "No". This indicates that the vast majority of students are already using AI technologies in the context of chemistry problem-solving.

In response to the question "How useful is AI for you in learning chemistry?", 56.6% of students indicated that it is mostly useful, 18.9% considered it very useful, and another 18.9% expressed a neutral opinion. Meanwhile, 5.7% of respondents stated that AI is mostly not useful. Notably, no respondents reported that AI is completely useless. These results suggest that students generally perceive AI as beneficial and widely applicable in the educational process, particularly in the context of learning chemistry.

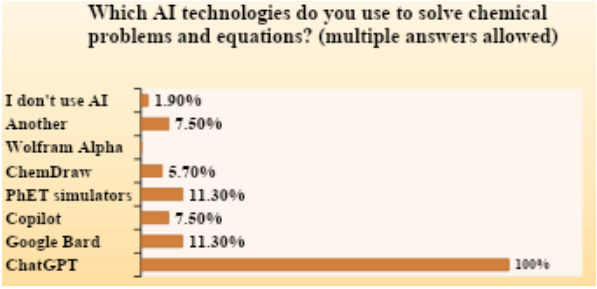


Figure 1 — Types of AI technologies used by respondents
Note: compiled by the authors.

In response to the question "Which AI technologies do you use to solve chemical problems and equations?", all students (100%) selected the generative chatbot ChatGPT (see Figure 1). This indicates that ChatGPT is in high demand within the educational system, particularly for students seeking and applying chemical information. Since this was a multiple-choice question, 11.3% of respondents also selected Google Bard, and another 11.3% indicated using PhET simulations. Additionally, 7.5% reported using the Copilot platform, while 5.7% chose ChemDraw. Notably, Wolfram Alpha was not selected by any respondents. A further 7.5% indicated using other types of platforms, and 1.9% of students reported not using any AI technologies at all.

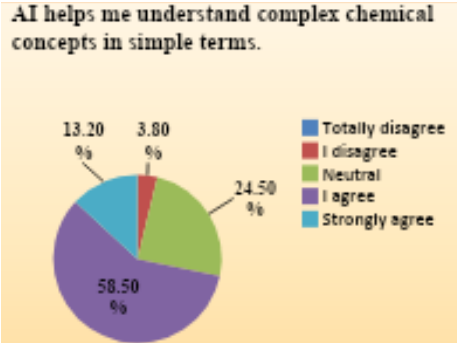


Figure 2 — AI support in understanding complex concept
Note: compiled by the authors.

Regarding the statement "AI helps me understand complex chemical concepts in simple terms", 31 students (approximately 58.5%) agreed, while 2 students (approximately 3.8%) disagreed. Additionally, 7 students (about 13.2%) strongly agreed, and 13 students (approximately 24.5%) remained neutral. Notably, none of the respondents expressed strong disagreement (see Figure 2).

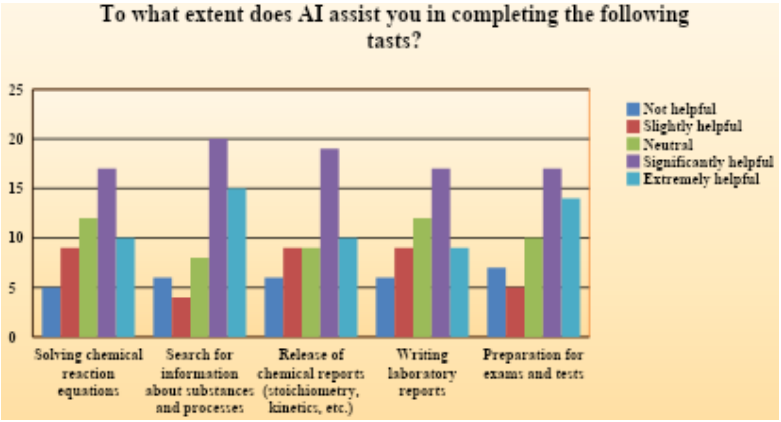
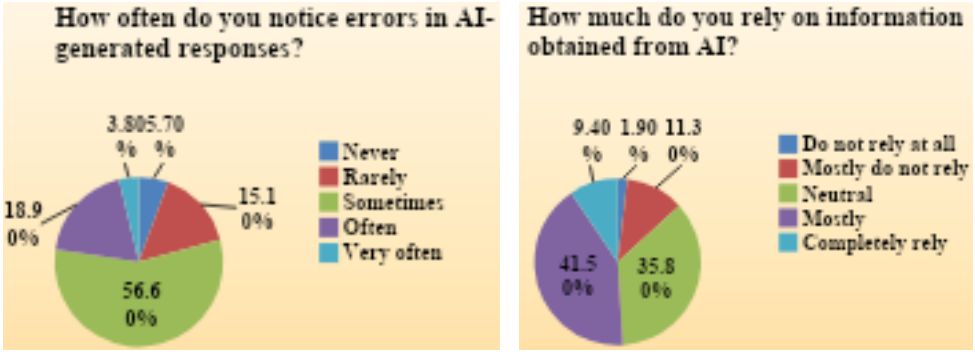


Figure 3 — Solving various problems with AI
Note: compiled by the authors.

This question clarifies in which situations and conditions AI helps students (see Figure 3). For the task of solving chemical equations, 10 students (18.8%) reported that AI was extremely helpful, 17 (32.07%) found it significantly helpful, 12 (22.64%) were neutral, 9 (16.98%) stated it was slightly helpful, and 5 (9.43%) indicated it was not helpful at all. In the task of searching for information about substances and processes, 15 students (28.3%) indicated that AI was extremely helpful, 20 (37.73%) considered it significantly helpful, 8 (15.09%) were neutral, 4 (7.54%) found it slightly helpful, and 6 (11.32%) stated it was not helpful. Regarding solving chemical problems (e.g., stoichiometry, kinetics), 10 students (18.8%) reported that AI was extremely helpful, 19 (35.84%) significantly helpful, 9 (16.98%) neutral, 9 (16.98%) slightly helpful, and 6 (11.32%) not helpful. For the section to writing laboratory reports, the largest number of students (17 students 32.07%) chose the option significantly helpful, while a small number of students (6 students 11.32%) chose the option not helpful. The last section was preparation for exams and tests, where a large number of students also chose the variant significantly helpful, and the smallest number of choices was in the variant slightly helpful by 9.43%.



(a) (b)

Figure 4 — Detection of AI errors (a) and respondents' reliance on AI (b)
Note: compiled by the authors.

In response to the question "How often do you notice errors in AI-generated responses?", 30 students (56.6%) answered "sometimes", 10 students (18.9%) answered "often", and 8 students (15.1%) stated they "rarely" notice errors. Only a small number of students reported that they "very often" notice errors (2 students) or "never" notice them (3 students) (see Figure 4-a).

Regarding the question "How much do you rely on information obtained from AI?", 22 students (41.5%) reported that they "mostly" rely on it, while 6 students (11.3%) stated they "mostly do not rely" on such information. A neutral position was expressed by 19 students (35.8%), while 5 students (9.4%) indicated they "completely rely" on AI-generated content. Only 1 student (1.9%) stated that they "do not rely at all" (see Figure 4-b). These results indicate that the majority of students tend to seek support from AI-generated information and demonstrate a general level of trust toward it.

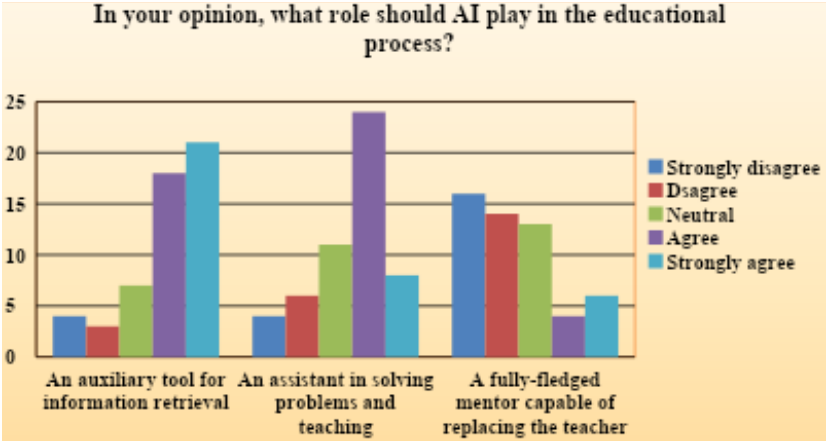


Figure 5 — The role of AI in the educational process
Note: compiled by the authors.

To understand students' perspectives on the role artificial intelligence should play in the educational process, a question was included in the survey evaluating three potential roles for AI (see Figure 5) an additional tool for information retrieval, an assistant in problem-solving and learning, and a full-fledged mentor capable of replacing the teacher. These roles were rated on a 5-point Likert scale, where 1=strongly disagree and 5=strongly agree. Regarding AI as an additional tool for information retrieval, 18 students (33.96%) agreed and 21 students (39.62%) strongly agreed. In contrast, 3 students (5.66%) disagreed and 4 (7.54%) strongly disagreed, while 7 students (13.2%) remained neutral. As for the role of AI as an assistant in problem-solving and instruction, 24 students (45.28%) agreed and 8 (15.09%) strongly agreed. Meanwhile, 6 students (11.32%) disagreed and 4 (7.54%) strongly disagreed; 11 students (20.75%) selected a neutral position. In contrast, the role of AI as a full-fledged mentor capable of replacing the teacher received much lower support: only 4 students (7.54%) agreed and 6 (11.32%) strongly agreed. A significant portion of students disagreed (14 students, 26.41%) or strongly disagreed (16 students, 30.18%), while 13 students (24.52%) remained neutral. These findings indicate that the majority of students do not view AI as capable of fully replacing the teacher, which reinforces the notion that artificial intelligence cannot substitute the human interaction and pedagogical relationship between teacher and learner.

The final question of the survey aimed to gather students' suggestions for improving the use of artificial intelligence in chemistry education. The responses included the following recommendations: the development of AI platforms in the Kazakh language; broader access to verified academic literature; the creation of interactive learning platforms; the need to equip schools with modern technologies before full-scale implementation of AI tools; the design of platforms that deliver accurate and reliable information; the integration of virtual simulations; the development of specialized platforms for solving chemistry problems; the automation of assessment to reduce teachers' workload; the possibility of assigning tasks based on students' learning levels; and a suggestion that AI tools be used primarily by teachers rather than students, as overreliance on AI may reduce learners' motivation to engage in independent research.

To evaluate the internal consistency of the survey instrument, Cronbach's Alpha reliability coefficient was calculated using SPSS. The analysis included 24 questionnaire items covering various aspects of ChatGPT usage in the academic activities of master's students (see Table 6). The resulting alpha value was α=0.855, indicating a high level of internal consistency. According to established thresholds, a coefficient above 0.8 is considered evidence of good reliability. Therefore, the developed questionnaire is deemed a reliable tool for subsequent data analysis.

Table 6 – Cronbach's Alpha coefficient value

Reliability statistics	
Cronbach's Alpha	0.855
Valid	53
Excluded[a]	0
Total	53
a-listwise deletion based on all variables in the procedure	

Note: compiled by the authors.

Additional reliability analysis by thematic blocks (perception, experience, and recommendations) showed Cronbach's Alpha values ranging from 0.82 to 0.87 confirming the reliability and consistency of the instrument.

A descriptive analysis of the data was also performed. This descriptive statistics showed the mean, standard deviation, and dispersion for each question in the survey. These data characterize the use of AI in the educational process. The results of the analysis provide general trends in the application of ChatGPT in chemistry education (see Table 7).

Table 7 – Results of the descriptive analysis

Descriptive statistics				
	N	*Mean*	*Standard deviation*	*Dispersion*
Question 1	*53*	*1,04*	*0,192*	*0,037*
Question 2	*53*	*3,96*	*0,678*	*0,460*
Question 3	*53*	*1,00*	*0,193*	*0,052*
Question 4	*53*	*3,81*	*0,709*	*0,502*
Question 5	*53*	*3,41*	*1,281*	*1,644*
Question 6	*53*	*3,28*	*0,907*	*0,822*
Question 7	*53*	*3,34*	*0,898*	*0,806*
Question 8	*53*	*3,00*	*0,855*	*0,731*
Question 9	*53*	*3,45*	*0,889*	*0,791*
Question 10	*53*	*3,30*	*0,932*	*0,869*
Question 11	*53*	*3,28*	*1,211*	*1,474*
Question 12	*53*	-	-	-
N valid	*53*			

Note: compiled by the authors.

Discussion. Analysis revealed that the chatbot answered 14 out of 18 questions correctly (77.77%). It also answered 1 question correctly, but did not provide a complete explanation. In addition, it answered 3 questions (16.66%) completely incorrectly. The most common mistakes were misunderstandings of chemical terms such as anode-cathode and anion-cation. There were also problems with solving stoichiometric tasks and equating reactions. In addition, there were difficulties in solving problems involving electrolysis and redox reactions.

When comparing ChatGPT's responses to the reference answers provided in the problem set, the following observations were made:

● ChatGPT is capable of solving basic and intermediate-level problems at the undergraduate level.

● In more complex or highly specialized topics (e.g., determining the composition of gas mixtures, writing the overall equation for molten electrolysis, the partially reduced reaction method, or balancing complete redox equations), the model tends to produce inconsistent or unreliable results.

● In some cases, ChatGPT offers explanations that are more accessible and easier to understand than those found in traditional textbooks.

In conclusion, the study identified several strengths of ChatGPT in the context of solving chemistry problems:

● Rapid generation of solutions and explanations;

● High accuracy in calculations, provided that the task is clearly formulated;

● Educational value, particularly in explaining fundamental concepts.

However, several limitations were also observed:

● Errors in complex calculations and highly specialized topics;

● The possibility of generating plausible-sounding but scientifically incorrect responses;

● Lack of interactive clarification when additional contextual information is required.

As a result of the study of the first question, the generative ChatGPT can be used as a supplementary tool for students of inorganic chemistry, but the answers must be verified. The model is effective in explaining theoretical foundations, but requires refinement for solving complex problems or conceptual learning.

Previous studies (Uçar et al., 2025) have also noted that AI makes errors in complex and logical tasks on chemistry lesson, taking into account the concept of reasoning. Also, J.Tyson's study (Tyson, 2023) demonstrated that ChatGPT makes mathematical and conceptual mistakes when solving chemistry tasks. Therefore, ChatGPT can only be used as an auxiliary tool in chemistry education.

The survey results revealed that the majority of students actively use artificial intelligence, and while some viewed it is a potential full-fledged mentor capable of replacing the teacher in the future, others perceived it solely as an auxiliary tool for information retrieval. Overall, the findings confirm that artificial intelligence – particularly the ChatGPT platform – is a widely used and in-demand technology in the context of chemistry education. ChatGPT was found to assistant students in analyzing complex concepts and solving problems, thereby supporting its value as an effective educational tool.

However, the analysis of student responses also revealed that the model is prone to errors when solving chemistry problems. This highlights the need for a critical approach to its application in the learning process, emphasizing the importance of integrating ChatGPT with verified sources and pedagogical support.

Conclusion. The use of artificial intelligence for generating and analyzing test items in chemistry allows educators to diversity instructional materials and adapt them to learners with varying levels of preparedness.

The application of GAI to solve and analyze inorganic chemistry problems offers teachers certain opportunities. According to the results of the study, ChatGPT 4.0 correctly solved inorganic chemistry tasks, demonstrating its ability to solve problems at the bachelor's level. However, it was also found to give incorrect answers when solving a number of complex multi-step problems. Therefore, when integrating GAI into the learning process, it should be used as a supplementary tool rather than a primary one.

In this regard, a survey was developed to determine how university students use AI in chemistry lessons. Statistical analysis was performed in SPSS to determine the reliability of the developed survey and to conduct a descriptive analysis. The reliability coefficient of the research tool was 0.855 (Cronbach's alpha coefficient = 0.855). The survey results showed that chatbots are perceived positively by students. Students noted that they use ChatGPT to solve problems and complete assignments in inorganic chemistry. This study will be an important step towards the future integration of AI into the chemistry learning process.

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