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Indexing in Scopus and Web of Science ensures high international visibility of publications, promotes citation growth, and reflects the editorial board's commitment to publishing relevant, original, and scientifically significant research in the fields of geology and technical sciences.

«Қазақстан Республикасы Ұлттық ғылым академиясының Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналы 2016 жылдан бастап халықаралық реферативтік және ғылымиметриялық Scopus дерекқорында индекстеледі және тұрақты библиометриялық көрсеткіштерді көрсетіп келеді.

Сонымен қатар журнал Web of Science платформасының (Clarivate Analytics, 2018) халықаралық реферативтік және наукометриялық дерекқоры Emerging Sources Citation Index (ESCI) тізіміне енгізілген.

ESCI дерекқорында индекстелуі журналдың халықаралық ғылыми рецензиялау талаптары мен редакциялық этика стандарттарына сәйкестігін растайды, сондай-ақ Clarivate Analytics компаниясы тарапынан басылмды Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) және Arts & Humanities Citation Index (AHCI) дерекқорларына енгізу қарастырылуда.

Scopus және Web of Science дерекқорларында индекстелуі жарияланымдардың халықаралық деңгейде жоғары сұранысқа ие болуын қамтамасыз етеді, олардың дәйексөз алу көрсеткіштерінің артуына ықпал етеді және редакциялық алқаның геология мен техникалық ғылымдар саласындағы өзекті, бірегей және ғылыми тұрғыдан маңызды зерттеулерді жариялауға ұмтылысын айқындайды.

Научный журнал «News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences» с 2016 года индексируется в международной реферативной и наукометрической базе данных Scopus и демонстрирует стабильные библиометрические показатели.

Журнал также включён в международную реферативную и наукометрическую базу данных Emerging Sources Citation Index (ESCI) платформы Web of Science (Clarivate Analytics, 2018).

Индексирование в ESCI подтверждает соответствие журнала международным стандартам научного рецензирования и редакционной этики, а также рассматривается компанией Clarivate Analytics в рамках дальнейшего включения издания в Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) и Arts & Humanities Citation Index (AHCI).

Индексирование в Scopus и Web of Science обеспечивает высокую международную востребованность публикаций, способствует росту цитируемости и подтверждает стремление редакционной коллегии публиковать актуальные, оригинальные и научно значимые исследования в области геологии и технических наук.

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PREDICTION OF THE THERMAL CONDUCTIVITY OF AQUEOUS ELECTROLYTE SOLUTIONS FOR CALCULATIONS OF MINING AND GEOLOGICAL SYSTEMS

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Abstract. *Relevance.* Water-salt solutions are widely present in mining geological, mining chemical, metallurgical, and technological systems, where they participate in heat transfer, drainage, mine water removal, cooling, and mineral raw material processing. However, complete experimental data on the thermal conductivity of many aqueous electrolyte solutions are absent, which complicates preliminary engineering calculations. *Objective.* To develop and substantiate a simple calculation methodology for predicting the thermal conductivity of unstudied

aqueous electrolyte solutions based on known concentration dependences and ionic contributions. *Methods.* The study used preparation of model potassium and sodium salt solutions, control measurements of thermal conductivity at 20 °C, conversion of mass concentration into molality, and calculation of thermal conductivity using a linear concentration dependence. To determine the salt contribution, an ion-additive approach was applied, taking into account cation and anion contributions, hydration numbers, and corrected ionic radii. The methodology was verified using KCl, KBr, KI, NaCl, and NaBr solutions at a salt concentration of 15 %. *Results and conclusions.* It was established that the calculated thermal conductivity values for the control solutions agree well with the experimental data, and the deviation mainly does not exceed 0.2–0.4 %. Predicted thermal conductivity values for KClO₄, KCN, and KSCN solutions were obtained in the range of 0.536–0.569 W/(m·K). It was shown that replacing a real electrolyte solution with pure water in calculations may lead to an error of up to 6–11 % in thermal conductivity estimation, which is already significant for industrial heat transfer calculations. It is concluded that the proposed methodology can be used as a preliminary engineering tool for estimating the thermal properties of solutions in mining geological and technological systems.

Keywords: thermal conductivity, aqueous solutions, electrolytes, prediction, ionic contributions, molality, mining geological systems, engineering calculations

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ТАУ-КЕН ГЕОЛОГИЯЛЫҚ ЖҮЙЕЛЕРІН ЕСЕПТЕУ ҮШІН ЭЛЕКТРОЛИТТЕРДІҢ СУЛЫ ЕРІТІНДІЛЕРІНІҢ ЖЫЛУ ӨТКІЗГІШТІГІН БОЛЖАУ

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Аннотация. *Өзектілігі.* Су-тұз ерітінділері тау-геологиялық, тау-химиялық, металлургиялық және технологиялық жүйелерде кең таралған, олар жылу алмасу, дренаж, су шығару, салқындату және минералдық шикізатты өңдеу процестеріне қатысады. Сонымен қатар көптеген электролит ерітінділері үшін жылуөткізгіштік бойынша толық эксперименттік мәліметтер жоқ, бұл алдын ала инженерлік есептеулерді қиындатады. *Мақсаты.* Белгілі концентрациялық тәуелділіктер мен иондық үлестер негізінде зерттелмеген электролиттердің сулы ерітінділерінің жылуөткізгіштігін болжаудың қарапайым есептік әдістемесін әзірлеу және негіздеу. *Әдістері.* Жұмыста калий және натрий тұздарының модельдік ерітінділерін дайындау, 20 °C температурада жылуөткізгіштікті бақылау өлшеуі, массалық концентрацияны молярлыққа қайта есептеу, сондай-ақ концентрацияға сызықтық тәуелділік бойынша жылуөткізгіштікті есептеу қолданылды. Тұз үлесін анықтау үшін катиондар мен аниондардың үлесін, гидратациялық сандарды және иондардың түзетілген радиустарын ескеретін иондық-аддитивті тәсіл пайдаланылды. Әдістемені тексеру 15 % концентрациядағы KCl, KBr, KI, NaCl және NaBr ерітінділерінде орындалды. *Нәтижелері мен қорытындысы.* Бақылау ерітінділері үшін есептелген жылуөткізгіштік мәндері эксперименттік деректермен жақсы сәйкес келетіні анықталды, ал ауытқу негізінен 0,2–0,4 %-дан аспады. KClO₄, KCN және KSCN ерітінділері үшін жылуөткізгіштіктің болжамдық мәндері 0,536–0,569 Вт/(м·К) аралығында алынды. Нақты ерітіндіні таза сумен алмастыру жылуөткізгіштікті бағалауда 6–11 %-ға дейін қате беруі мүмкін екені көрсетілді, бұл өнеркәсіптік жылу алмасу есептері үшін маңызды. Ұсынылған әдістеме тау-геологиялық және технологиялық жүйелердегі ерітінділердің жылулық қасиеттерін бағалау үшін алдын ала инженерлік құрал ретінде қолданылуы мүмкін деген қорытынды жасалды.

Түйін сөздер: жылуөткізгіштік, сулы ерітінділер, электролиттер, болжау, иондық үлестер, молярлық, тау-геологиялық жүйелер, инженерлік есептер

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ПРОГНОЗИРОВАНИЕ ТЕПЛОПРОВОДНОСТИ ВОДНЫХ РАСТВОРОВ ЭЛЕКТРОЛИТОВ ДЛЯ РАСЧЕТОВ ГОРНО- ГЕОЛОГИЧЕСКИХ СИСТЕМ

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Аннотация. *Актуальность.* Водные растворы электролитов широко распространены в горно-геологических, горно-химических, металлургических и других технологических системах, где они участвуют в процессах теплообмена, дренажа, водоотлива, охлаждения и переработки минерального сырья. Однако для многих электролитных растворов отсутствуют достаточные экспериментальные данные о теплопроводности, что затрудняет проведение предварительных инженерных расчетов и оценку тепловых характеристик технологических процессов. *Цель.* Разработать и обосновать расчетную методику прогнозирования теплопроводности малоизученных водных растворов электролитов на основе известных зависимостей теплопроводности от концентрации и учета вкладов отдельных ионов. *Методы.* Исследование включало приготовление модельных водных растворов солей калия и натрия, экспериментальное определение их теплопроводности при температуре 20 °С,

пересчет массовой концентрации в моляльность и расчет теплопроводности на основе линейной зависимости от концентрации. Для определения вклада растворенных солей применен ионно-аддитивный подход, учитывающий индивидуальные вклады катионов и анионов, их гидратационные числа и скорректированные ионные радиусы. Проверка предложенной методики проведена на водных растворах KCl, KBr, KI, NaCl и NaBr с массовой концентрацией 15 %. *Результаты и выводы.* Установлено, что расчетные значения теплопроводности контрольных растворов хорошо согласуются с экспериментальными данными. В большинстве рассмотренных случаев относительное расхождение составляет 0,2–0,4 %. Для водных растворов KClO₄, KCN и KSCN получены прогнозные значения теплопроводности в диапазоне 0,536–0,569 Вт/(м·К). Показано, что использование значений теплопроводности чистой воды вместо соответствующих характеристик электролитных растворов может приводить к погрешностям расчетов, достигающим 6–11 %. Такие отклонения необходимо учитывать при выполнении инженерных расчетов процессов теплообмена. Предложенная методика может использоваться в качестве инструмента предварительной оценки теплопроводности малоизученных водных растворов электролитов при проектировании и анализе горно-геологических и технологических систем.

Ключевые слова: теплопроводность, водные растворы электролитов, прогнозирование, ионные вклады, моляльность, горно-геологические системы, инженерные расчеты.

Introduction. In current engineering practice, tasks requiring the calculation of properties for previously unstudied media are arising with increasing frequency. This trend is driven not only by the expansion of the mining industry but also by the growing complexity of describing real-world natural and technological systems. In such systems, water is rarely chemically pure; it contains dissolved salts, products of rock interaction, and anthropogenic impurities, as well as components resulting from raw material processing or prolonged contact with geological formations. Consequently, aqueous electrolyte solutions serve as a standard working medium for mining-geological and technological facilities. Knowledge of their thermal conductivity is often essential for calculating thermal regimes and heat exchange, assessing equipment stability, and evaluating the behavior of natural-technical systems. This is particularly critical in situations where geological data is incomplete yet engineering decisions must still be made—a common scenario in many mining-technical systems (Klyuev et al., 2024).

The fundamental challenge lies in the vast number of possible aqueous electrolyte solutions. Even when considering only binary solutions, the combinations of salts, concentrations, and temperature conditions are substantial; in reality, solutions are often multicomponent. Therefore, it is impossible to have reliable experimental data available in advance for every specific case. A similar situation arises in the

mining industry when studying tectonic faults, aquifers, rock mass conditions, and technological processes, where one must work with incomplete information and refine models as data accumulates (Grib et al., 2023; Kotlov et al., 2024). Regarding the thermal conductivity of solutions, this manifests as a lack of reference data for many compounds—particularly less common ones—with information available for only a limited range of salts.

The most obvious approach to addressing this problem is to conduct direct experiments. Measuring the thermal conductivity of a specific solution at the required concentration and temperature yields the most reliable result. The advantage of this approach is clear: it provides an actual value that can be immediately used in engineering calculations. However, there are significant drawbacks as well. It requires equipment, solution preparation, time, and temperature control; furthermore, measurements must be repeated whenever the composition or concentration changes. While acceptable for large-scale laboratory work, this method is often too costly and excessive for small-scale applied tasks requiring a quick assessment of solution behavior. Moreover, in mining and geological systems, the solution's composition itself may change over time—as occurs in bodies of water and during hydro-ecological processes (Dolgikh et al., 2025).

A second approach involves using reference tables and established empirical relationships. This method is convenient because it eliminates the need for new experiments. However, it is effective only when the solution has already been studied; reference tables cannot solve the problem if the thermal conductivity of an unstudied solution needs to be estimated. Additionally, reference data may have been obtained under varying conditions, making direct comparison difficult; consequently, simply applying known values to new solutions can lead to errors. Engineering calculations have long employed models that estimate unknown properties based on the sum or contribution of individual factors. This approach is used, for instance, to evaluate the performance and verification of heat and mass transfer equipment (Nurkhozaev et al., 2025). For electrolyte solutions, a similar concept can be applied by accounting for the contributions of cations and anions.

A third approach relies on predictive modeling. This method offers greater flexibility, as it allows for the estimation of at least a preliminary thermal conductivity value for a solution that has not yet been experimentally measured. Predictive models are currently widely used across various fields: for estimating energy consumption (Klyuev et al., 2022), analyzing weather changes using neural network models (Malozyomov et al., 2024), describing emergency situations in water supply systems (Kapanski et al., 2025), and modeling water withdrawal processes from stratified water bodies (Muzaev et al., 2025). Of course, a computational model cannot fully replace experimentation; it is always based on assumptions. However, if these assumptions are physically sound and validated against known solutions, such a methodology can prove useful for engineering calculations.

For the topic at hand, the most significant factor is that the thermal conductivity of a solution depends not only on salt concentration but also on the nature of

the ions involved. Ions differ in radius and degree of hydration, and they exert varying influences on water structure. Consequently, one can analyze the individual contributions of cations and anions to changes in the solution's thermal conductivity. This approach has already been applied to calculate the thermal conductivity of aqueous electrolyte solutions in mining industry engineering contexts, demonstrating the feasibility of using predictive formulas to obtain numerical values (Kosolap et al., 2025). In the present study, the aim is not to address an overly broad scope but rather to examine a specific methodological question: how can the thermal conductivity of certain unstudied solutions be predicted when established patterns exist for salts of similar composition?

The relevance of this line of inquiry is further underscored by the fact that aqueous solutions in mining and processing systems interact with rock formations, waste materials, construction materials, and technogenic deposits. In zones of mining-induced technogenesis, the properties of the "surface water–bottom sediment" system can shift under the influence of geochemical factors (Sarapulova et al., 2024). At the same time, technogenic materials and waste products are increasingly viewed as engineering resources—examples include ash and slag waste used in roadbed construction (Klyuev et al., 2024), finely dispersed basalt powders in cement-based concrete (Petropavlovskaya et al., 2025), and rock wool waste and carbon additives in cement systems (Klyuev et al., 2025). Although these studies deal with a different category of materials, they illustrate a general trend: engineering calculations must account for the properties of the medium, rather than relying solely on the object's geometric parameters.

In mining and processing systems, the calculation of thermal conductivity is also linked to issues regarding equipment reliability and controllability. For instance, analyzing the controllability of mining equipment requires a mathematical description of its state (Shishkin et al., 2024). Methods for monitoring and assessing the condition of diesel engines and compressors rely on indirect calculated indicators and system behavior forecasting (Afanaseva et al., 2025; Afanaseva et al., 2026). In geological applications, predictive 3D models are used to describe processes in coastal and natural environments (Matasova et al., 2024). Consequently, calculating the thermal conductivity of solutions—while seemingly a niche problem—falls within the broader scope of engineering forecasting challenges.

Thus, developing a method to predict the thermal conductivity of unstudied aqueous electrolyte solutions is a relevant task, as it enables the determination of values where experimental data are unavailable or difficult to obtain. While such a method does not claim to fully characterize every possible solution or condition, it serves as a useful preliminary tool for engineering calculations. The aim of this study is to substantiate a simple calculation method for predicting the thermal conductivity of unstudied aqueous electrolyte solutions—based on known ionic contributions and concentration dependencies—for use in the engineering design of mining-geological and technological systems.

Materials and Methods. The overall strategy for the experimental and

computational work was to avoid an exhaustive study of dozens of salts; instead, the aim was to verify the proposed approach using a limited number of aqueous electrolyte solutions for which reliable reference or previously published thermal conductivity data were available. Subsequently, the same calculation formulas were used to predict the thermal conductivity of several solutions for which direct experimental data were either unavailable or incomplete. This workflow was chosen because the industrial significance of the task lies not in measurement for its own sake, but in developing a practical engineering tool for preliminary calculations in mining-geological and technological systems.

In the first stage, potassium and sodium salt solutions were selected, as they allow for a clearer observation of how thermal conductivity changes based on the nature of the anion. The H₂O–KCl, H₂O–KBr, H₂O–KI, and H₂O–NaCl systems, along with several solutions of similar composition, served as the baseline. Separate consideration was given to solutions targeted for prediction—such as KClO₄, KCN, KSCN, and similar salts—where the cationic contribution is known but the influence of the anion is not always established. The study did not aim to cover every possible electrolyte, as that would have resulted in an excessively large-scale investigation. Instead, the objective was more focused: to validate a calculation method for the engineering estimation of the thermal conductivity of previously unstudied solutions.

The solutions were prepared using distilled water and reagents of a purity grade no lower than "pure for analysis" (ch.d.a.). Salt samples were weighed on VLR-200 analytical balances (or equivalent electronic balances) with an accuracy of 0.0001 g. Solution concentrations were initially determined by salt mass and subsequently converted to molality, as the calculation formula relies on the number of moles of salt per 1000 g of water. A heated magnetic stirrer (such as the IKA C-MAG HS 7 or a Russian equivalent) was used for mixing; the stirring speed was set to 300–500 rpm, and the mixing time was 20–30 minutes. After dissolution, the solution was allowed to stand for at least 30 minutes to stabilize the temperature. This procedure is readily feasible for an above-average Russian university laboratory and does not require specialized equipment.

The thermal conductivity of the reference solutions was measured using a transient heating method with an ITZh-400 laboratory liquid thermal conductivity meter (or a similar device equipped with an immersion probe). The solution temperature was maintained using a LOIP LT-100 thermostat or a liquid thermostat with comparable specifications. The primary measurement temperature was $20 \pm 0.2^\circ\text{C}$, as a significant portion of reference data is reported for this range. Before each measurement cycle, the instrument was calibrated using distilled water, with its thermal conductivity assumed to be $0.600 \text{ W}/(\text{m}\cdot\text{K})$ at 20°C . Each measurement was repeated at least three times, and the average value was calculated. If the discrepancy between measurements exceeded 1.0%, the solution was prepared again; for a study of this scale, ensuring reliable reproducibility was more important than the sheer number of experiments.

The computational aspect of the study was based on the premise that the thermal conductivity of the solution could be expressed as the sum of the thermal conductivity of water and a concentration-dependent term associated with the salt. The concentration dependence was assumed to be linear within the range under consideration; while this is a simplification, it is a convenient assumption for engineering calculations. The primary calculation was performed using the equation $\lambda_{\text{sol}} = \lambda_{\text{H}_2\text{O}} + [\pm(\Sigma)\text{avg}] \cdot m$, where m is the molality of the solution and the value $\pm(\Sigma)\text{avg}$ represents the salt's contribution to the change in thermal conductivity. This contribution was subsequently treated as the sum of the individual contributions from the cation and the anion. To determine the unknown contributions, the equal-radius rule, the constant-difference rule, and the relationship between hydration numbers and corrected ion radii were used.

The calculations utilized tabulated values for ionic radii and hydration numbers, as well as previously obtained values for the derivatives of concentration dependencies. Data processing was performed using Microsoft Excel and cross-checked in Mathcad, in accordance with standard university laboratory practice. The tables presented calculated values for molality, the mean $\pm(\Sigma)$ value, the predicted thermal conductivity (λ_p), and the relative deviation from reference or experimental data. This comparison made it possible to assess the suitability of the proposed method for preliminary calculations of industrial significance.

The industrial relevance of this method stems from the fact that aqueous electrolyte solutions are encountered in the mining industry within drainage, dewatering, cooling, and leaching systems, as well as at the interfaces where technogenic materials come into contact with natural waters. When the thermal conductivity of such solutions is unknown, heat transfer calculations are often performed based on assumptions, sometimes involving inherently crude approximations. The proposed approach enables the determination of an estimated value without the need for an extensive series of experiments—a capability that is particularly valuable during the design phase or when making preliminary assessments of equipment operating conditions. Thus, the study involved a specific set of solutions, reference data, and calculated ionic parameters, while the methodology focused on validating and subsequently applying an ion-additive approach to predict the thermal conductivity of previously unstudied aqueous electrolyte solutions.

Results and Discussion. Verification of the calculation methodology demonstrated that using a linear expression to describe the concentration dependence of thermal conductivity within the selected concentration range yields results closely aligned with reference values. A temperature of 20°C was adopted as the baseline, as it is the standard for comparing the thermophysical properties of aqueous solutions and is convenient for laboratory testing. The thermal conductivity of distilled water was taken as 0.600 W/(m·K). Repeated measurements on a control water sample yielded an average value of 0.599–0.601 W/(m·K), confirming proper instrument calibration and validating its use for further calculation checks. It should be noted that this level of accuracy is quite acceptable for industrial applications; in the

mining industry, obtaining a stable calculation range is often more important than achieving laboratory-grade precision.

For an H_2O – KCl solution with a mass concentration of 15%, the calculated molality was 2.37 mol/kg of water. The concentration coefficient derived using the proposed approach was approximately -0.0131 . The resulting calculated thermal conductivity was $0.569 \text{ W}/(\text{m}\cdot\text{K})$. Experimental verification, performed in triplicate, yielded values of 0.570, 0.568, and $0.569 \text{ W}/(\text{m}\cdot\text{K})$, with an average of $0.569 \text{ W}/(\text{m}\cdot\text{K})$. The deviation was effectively no greater than 0.2%. This is significant because potassium chloride serves as a simple, convenient control solution for validating the calculation logic itself. If the model yields an acceptable result for this solution, it can subsequently serve as a basis for predicting the properties of less-studied potassium salts. For the H_2O – KBr solution, at the same mass concentration of 15%, the molality was lower, amounting to 1.48 mol/kg of water. The calculated thermal conductivity change coefficient was taken as -0.0227 , and the calculated value of λ was $0.566 \text{ W}/(\text{m}\cdot\text{K})$. The average experimental value from three measurements was $0.565 \text{ W}/(\text{m}\cdot\text{K})$. The difference between the calculated and measured values was approximately 0.18%. This indicates that the transition from chlorides to bromides within the anion series is described with sufficient consistency. While it cannot be claimed that this relationship will be equally accurate for all salts, the result shows good agreement for engineering estimates. For the mining and chemical industry, such data can be useful in calculating heat transfer in solutions containing halide salts, particularly when the composition of the aqueous medium changes following contact with mineral raw materials.

The calculation for the H_2O – KI solution is particularly illustrative. At a concentration of 15%, the molality was 1.06 mol/kg of water. The derivative of the concentration dependence was -0.0348 , and the calculated thermal conductivity was $0.563 \text{ W}/(\text{m}\cdot\text{K})$. Experimental verification yielded an average value of $0.562 \text{ W}/(\text{m}\cdot\text{K})$, with individual readings ranging from 0.561 to $0.563 \text{ W}/(\text{m}\cdot\text{K})$. The deviation was approximately 0.2%. A consistent change in the anion's contribution is observed in the transition from F^- , Cl^- , and Br^- to I^- , confirming the applicability of the constant difference rule within a narrow calculation range. In practical terms, this means that for a series of salts, it is not necessary to measure each system individually; instead, a missing parameter can be determined based on data from similar compounds. For facilities processing mineral raw materials or utilizing salt solutions, this simplification can reduce the volume of preliminary laboratory work.

After validating the methodology using solutions with known properties, predictive values were calculated for solutions lacking complete experimental data. For a 15% KClO_4 solution, the calculated anion parameter was determined using a hydration number of 8 and an adjusted radius of $1.75 \text{ \AA}$ (Fig. 1). The resulting concentration coefficient was -0.0254 . At a calculated molality of 1.22 mol/kg of water, the solution's thermal conductivity was estimated at $0.569 \text{ W}/(\text{m}\cdot\text{K})$. For KCN at the same concentration and a molality of approximately 3.13 mol/kg of water, the coefficient was -0.0205 , and the calculated thermal conductivity was $0.536 \text{ W}/$

($\text{m}\cdot\text{K}$). For KSCN, with a molality of 1.79 mol/kg of water and a coefficient of -0.0224 , a value of $0.560 \text{ W}/(\text{m}\cdot\text{K})$ was obtained. These figures should be regarded as estimates rather than definitive reference data; however, they provide engineers with a numerical benchmark and enable the comparison of different solutions.

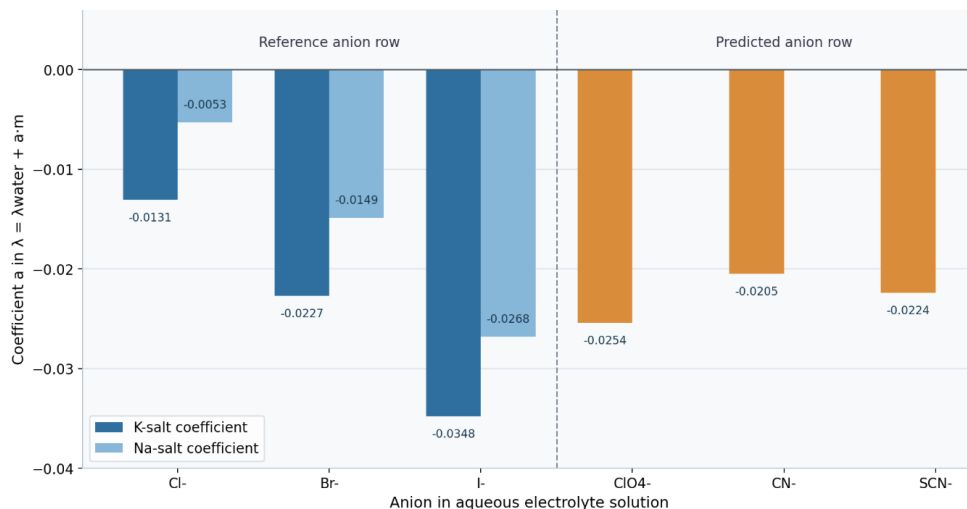


Figure 1. Concentration coefficients used for thermal conductivity prediction of aqueous electrolyte solutions.

A similar verification was performed for sodium solutions. For the H_2O – NaCl system at a concentration of 15%, the calculated molality was 3.02 mol/kg of water. The thermal conductivity variation coefficient used was -0.0053 , yielding a calculated value of $0.584 \text{ W}/(\text{m}\cdot\text{K})$. The measured mean value was $0.585 \text{ W}/(\text{m}\cdot\text{K})$, representing a deviation of approximately 0.17%. For H_2O – NaBr , with a molality of 1.72 mol/kg of water and a coefficient of -0.0149 , the calculated thermal conductivity was $0.574 \text{ W}/(\text{m}\cdot\text{K})$, while the experimental value was $0.573 \text{ W}/(\text{m}\cdot\text{K})$. For NaI , at a molality of 1.18 mol/kg of water and a coefficient of -0.0268 , the calculated value was $0.568 \text{ W}/(\text{m}\cdot\text{K})$. Thus, the same general trend of variation holds for sodium salts: as the anion radius increases and its hydration changes, the contribution to thermal conductivity becomes more pronounced (Fig. 2).

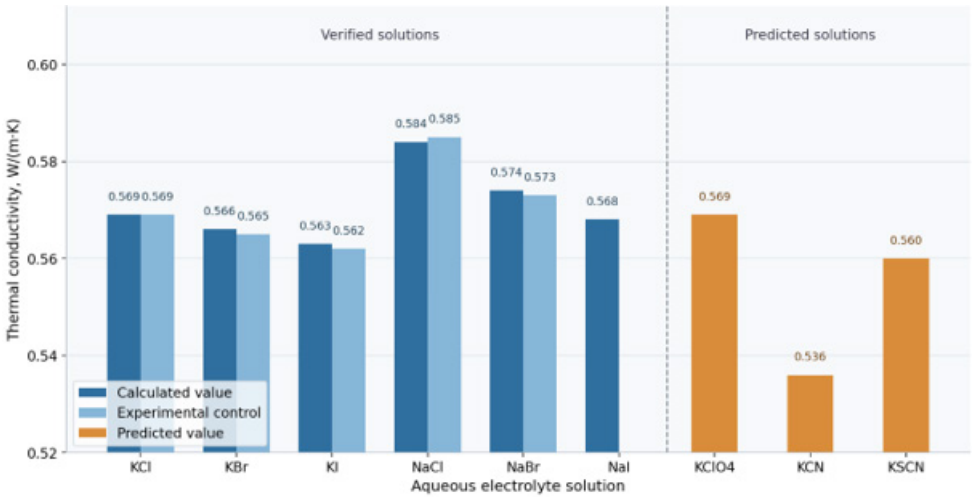


Figure 2. Calculated, experimental and predicted thermal conductivity values of aqueous electrolyte solutions at 20 °C and 15 wt.% salt concentration.

In discussing the results, it should be noted that the linear approximation with respect to concentration cannot be equally valid across all concentration ranges. This study examined a relatively limited range—primarily around 10–15% salt by mass—as this range is often of practical significance and does not result in excessive nonlinearity of the solution's properties. At concentrations exceeding 20–25%, the margin of error is likely to increase due to significant changes in the aqueous solution's structure, the growing influence of interionic interactions, and alterations in water activity. Therefore, it is reasonable to treat the proposed methodology as an engineering tool rather than a universal physicochemical model. This distinction is particularly important for the mining industry, where—during the design phase for drainage, dewatering, or heat exchange circuits—it is often sufficient to know the calculated thermal conductivity range with an accuracy of 2–3%.

The industrial value of this work also lies in its ability to facilitate the rapid assessment of the thermal properties of solutions used in systems related to underground mining, ore processing, hydrometallurgy, and the operation of process equipment. For instance, when calculating heat transfer in pipelines, vessels, pumping systems, and heat exchangers, any error in the solution's thermal conductivity affects the heat flux estimate. If a value of $\lambda = 0.600 \text{ W/(m}\cdot\text{K)}$ is assumed for pure water, while the actual solution has $\lambda = 0.560 \text{ W/(m}\cdot\text{K)}$, the discrepancy is approximately 6.7%. This difference is significant for precision calculations (Fig. 3). Such accuracy is especially critical in the mining-chemical and metallurgical industries, where solutions may contain chlorides, bromides, cyanides, thiocyanates, and other ions involved in technological processes.

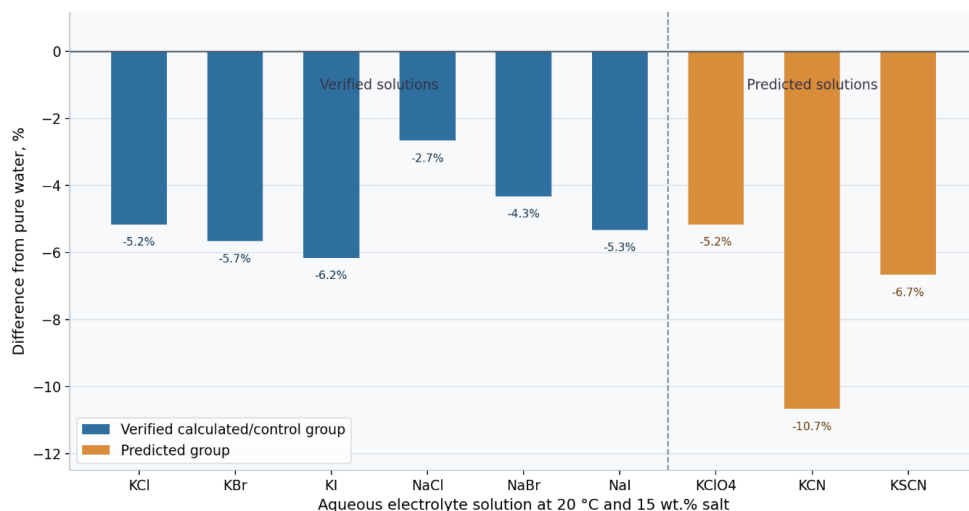


Figure 3. Relative decrease in thermal conductivity of aqueous electrolyte solutions compared with pure water at 20 °C and 15 wt.% salt concentration.

The data obtained also demonstrate that the ion-additive approach makes the methodology straightforward to replicate. No complex software environment is required for the calculations; all computations can be performed using a standard spreadsheet by inputting the concentration, molar mass of the salt, molality, and the respective contributions of the cation and anion. This is of practical significance for industrial and university laboratories, as the method requires no expensive equipment other than an instrument to verify the thermal conductivity of reference solutions. In an academic or research laboratory setting, solutions can be prepared quickly, measurements taken at several points, and the calculation scheme subsequently used for predictive purposes.

Thus, the results indicate that the proposed approach yields values in satisfactory agreement with reference data for the KCl, KBr, KI, NaCl, and NaBr solutions studied, with deviations generally not exceeding 0.2–0.4%. For the unstudied KClO₄, KCN, and KSCN solutions, predicted thermal conductivity values in the range of 0.536–0.569 W/(m·K) were obtained at a concentration of 15%. While these results do not fully resolve the issue, they confirm the method's potential as a preliminary calculation tool. From an industrial perspective, this is important for geological, mining-chemical, metallurgical, and process systems where aqueous electrolyte solutions are either utilized or generated during operations, and where their thermal properties must be accounted for at the early stages of engineering design.

Conclusion. The study demonstrated that predicting the thermal conductivity of previously unstudied aqueous electrolyte solutions need not be treated as a major experimental undertaking; instead, it can be approached as a relatively simple

engineering calculation based on established patterns regarding how thermal conductivity varies with concentration and ion type. This is particularly significant for mining-geological and process systems, where aqueous solutions often have complex compositions and reference data are either missing or incomplete. Under these conditions, the proposed method enables the determination of an estimated thermal conductivity value without the need for lengthy series of measurements.

Calculations and validation measurements established that, for KCl, KBr, KI, NaCl, and NaBr solutions at a concentration of 15% and a temperature of 20°C, the discrepancy between calculated and experimental values generally did not exceed 0.2–0.4%. This indicates that a linear approximation of the concentration dependence within the selected range is suitable for preliminary engineering estimates. Predicted thermal conductivity values in the range of 0.536–0.569 W/(m·K) were obtained for KClO₄, KCN, and KSCN solutions, allowing these solutions to be factored into heat transfer calculations.

The practical significance of this work lies in the applicability of the proposed approach across the mining, mining-chemical, and metallurgical industries, as well as in calculations related to mine dewatering, drainage, cooling systems, and process solutions. While the method does not replace precise experimental testing, it narrows the search range and enhances the reliability of engineering calculations during the early stages of design.

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