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METHODS OF SEPARATION OF TUNGSTEN AND MOLYBDENUM IN THE PROCESSING OF TUNGSTEN WASTE

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Abstract. The recycling of tungsten waste is now a critical concern. The industry now recycles waste from hard alloys and metallic tungsten, but seldom recycles trash from tungsten-containing molybdenum. This discrepancy arises from the challenge of distinguishing these two components. Furthermore, the SPA (Scientific and Productive Association) JSC Almalyk MMC did not engineer a system for purifying tungstate solutions from molybdenum and until recently, no technology existed for such purification. This article discusses theoretical concerns in the chemistry of tungsten and molybdenum. It also discusses a method for purifying mother liquors that have crystallized from molybdenum ammonium vapour tungstate. At SPA JSC Almalyk MMC, a process chain was established, enabling the company to manufacture tungsten products with a high molybdenum content this year. Pure metallic tungsten, devoid of molybdenum contaminants, has enhanced physical and thermoionic characteristics. Processing metallic molybdenum devoid of tungsten is more straightforward. The conversion of oxides into metal does not separate tungsten from molybdenum, hence requiring the separation of pure oxides. Tungsten and molybdenum exhibit identical configurations of outer electron shells, nearly equivalent atomic radii (Mo-1.36 A₀, W-1.37 A₀) and matching ionic radii (Mo^{4+} - 0.68 A₀, W^{4+} - 0.68 A₀); this similarity accounts for their comparable physical, mechanical and chemical properties, their concurrent occurrence in ore materials and the significant challenge of achieving complete separation.

Keywords: *SPA, Almalyk MMC, hard alloys, tungsten, metallic tungsten, NMMP, NaOH, Na_2CO_3, titration, molybdenum.*

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1. Introduction

The infrequent availability of tungsten, which is the second rarest metal among the top 20 globally and molybdenum (Han *et al*., 2021), renders the utilization of waste from these metals in production significantly economically advantageous (Morell *et al*., 2025). The characterization of metal composition and economic assessment can be done through shredding and screening processes (Wang *et al*., 2016). The use of waste is complicated by the fact that, as a result of their collection, molybdenum and tungsten waste often

arrive mixed (Parmonov *et al*., 2024). Ammonium hydroxide dissolves molybdic acid, which then undergoes processing alongside the primary production's solutions.

Metallic tungsten does not dissolve in the solution during this sort of processing, but rather remains as a solid residue that is then transferred to the tungsten department (Omole *et al*., 2022). The most economical and technologically easy process for processing tungsten waste is the method of fusing it with nitrate (Shemi *et al*., 2018). This method allows you to easily and quickly transfer all the tungsten into a solution in the form of sodium tungstate (Bao *et al*., 2020). Thus, for unmixed waste, there are processing methods that allow you to obtain conditioned tungsten and molybdenum salts (Vucko *et al*., 2024).

Results from an experiment on nickel-based alloy weldments and stainless steels indicate that when chloride accumulates on them, incinerators can rust. When it comes to handling tungsten waste that contains molybdenum, the situation is considerably worse (Xia *et al*., 2023). Mathematical model and reaction mechanism of molybdenum and tungsten extraction with TRPO from peroxide solution. When fused, both metals pass into solution equally well, but the tungsten compounds obtained from these solutions are substandard in molybdenum content (Vayakis *et al*., 2008).

This criterion covers leftovers left over after processing molybdenum waste in addition to the actual tungsten waste (Cai *et al*., 2022). To isolate tungsten compounds from solutions obtained by fusion of waste with nitrate that meet technical conditions in terms of molybdenum content (Parmonov *et al*., 2024), remarkable purification must be carried out (Smith & Cantor, 1987). Tungsten and molybdenum form a series of thio compounds, the formation of which made it possible to develop methods for separating tungsten and molybdenum. The best way to separate molybdenum trisulfide is first to make molybdenum thio salts and then break them down into molybdenum sulfide (Pushie & George, 2011). However, these compounds have been very little studied, especially their behaviour in solutions. Therefore, an attempt was subsequently made to study these compounds by potentiometric titration (Erickson & Helz, 2000). The most detailed syntheses of tungsten and molybdenum thio salts were first described by Berzelius and then by Krüss; later, Fernandez proved the existence of thiopara compounds with both oxygen completely replaced by sulfur and partially (Mutalova *et al*., 2024). It appears that obtaining a complete series of compounds is possible.

$$MeWO_3S \rightarrow MeWO_2S_2 \rightarrow MeWS_4 MeMoO_3S \rightarrow MeMoO_2S_2 \rightarrow MeMoOS_3 \rightarrow MeMoS_4$$

It is not possible to combine Me-Na^+, K^+ and NH_4^+ in water solutions by adding a solution of $(NH_4)_2S$ or saturation with H_2S. The only exception is for K_2WO_4 solutions. This is especially true for sodium salts, but a paper that was just released suggests that it is possible to make sodium thiosalts by treating them with water vapour. To learn more, we made different tungsten and molybdenum compounds with sulfide sulfur (thiosalts) using the traditional methods that Berzelius and Fernandez explained (Kamat-Vernekar, 2001).

2. Materials and Methods

The methods described in the literature make it possible to obtain di and tetra salts of tungsten and molybdenum. First, ammonium thiosalts was obtained, which was the great interest for the study. The obtained crystals of thiosalts exactly corresponded to the

descriptions available in the literature. Table 1 shows the analyses of the compounds obtained.

Table 1. Chemical composition of the obtained Thio compounds

Name of the Compound	Percentage (%)			Ratio Mo/S	Name of the Compound	Compound, (%)			Ratio Mo/S
	Me	S	NH_3			Me	S	NH_3	
$(NH_4)_2WS_4$	66.5[x] ±0.3	38.9±0.3	9.6±0.1	1:4.2	$(NH_4)_2MoS_4$	37.3±0.2	48.13±0.31	-	1:3.87
$(NH_4)_2WO_2S_2$	71.6[x] ±0.5	19.2±0.2	10.5±0.2	1:1.94	-	37.4±0.3	52.49±0.23	11.56±0.12	1:4.2
$(NH_4)_2MoS_2$	36.4±0.3	51.9±0.4	-	1:4.2	$(NH_4)_2MoO_2S_2$	42.1±0.2	28.94±0.31	-	1:2.06

Note: x) in terms of WO_3

All of the compounds we obtained are either normal tungstates or normal molybdates, as is completely clear from the formulas provided in the Table 1 (Erdőhelyi *et al*., 2001) described paramolybdate-like molybdenum thio compounds. A solution of ammonium sulfide and ammonium molybdate was mixed with hydrochloric acid. A precipitate that was distinct in color from the solution itself developed at a particular pH range (6-7).

The precipitate was filtered and analyzed. The chemical analysis data of the precipitate showed that, depending on the experiment, it may contain different compounds (Gassan *et al*., 2025). Thus, in one case, a compound corresponding to dimolybdate ($(NH_4)_2O{\cdot}2MoOS_2$) was obtained and in the other, thymolybdate ($(NH_4)_2O{\cdot}3MoOS_2$). It is characteristic that in all cases it was not possible to get a fully substituted thiosalt (i.e., a salt with the MoS_3 group).

The difference in the pH of the solution during precipitation explains the differences in the obtained compounds. The ability of tungstates and molybdates to form parasalts during evaporation of their ammonia solutions is well known. We attempted to obtain paracels by evaporation. Table 2 presents the analysis results of the crystals obtained during evaporation.

Table 2. Composition of polythiosalts obtained by evaporation of the solution $(NH_4)_2\ MeO_4+(NH_4)_2S$

№	Solution (original)	Composition of compounds			Ratio	
		Me, %	S, %	NH_3%	Me:S	$(NH_4)_2O$:Me
1/1	thiomolybdate solution	33.57±0.43	22.5±0.23	4.12±0.03	1:2.039	1:2.885
2/1		46.78±0.31	23.86±0.21	5.65±0.04	1:1.915	1:2.935
2/1		48.94±0.33	29.64±0.26	6.17±0.04	1:1.819	1:2.815
2/2		49.32±0.36	30.58±0.27	6.23±0.04	1:1.910	1:2.86
	thio-tungstate	80.5[x] ±0.7	0.81±0.32	5.73±0.04	-	-
		85.3[x] ±0.8	0.18±0.09	5.32±0.02	-	1:2.45

Note: x) in terms of WO_3

Table 2 shows that when ammonium molybdate solutions evaporate in a mix, they leave behind a salt with the formula $(NH_4)_2O{\cdot}MoOS_2$. When solutions of ammonium tungstate and sulfide evaporate, they leave behind ammonium paratungstate that is slightly contaminated with sulfur.

The sulfur ion effortlessly replaces the oxygen atom in the oxygen compounds of tungsten and molybdenum. However, most researchers think that a large group of heteropoly compounds are made by adding the Me_2O_7 group to the oxygen atoms of some

acids, which are often just ideas (Khasanov *et al*., 2024). The possibility of replacing oxygen with thio groups instead of oxy-groups is intriguing not only for the synthesis of a new group of compounds but also for theory. To get phosphoric molybdenum heteropoly acids was picked up by this method.

The only difference was that a MoS_3 group was added instead of a MoO_3 group during the reaction. The crystals obtained from the solution and the precipitate during the synthesis was analysed (Shabelnikova & Suvorova, 2025). It turned out that the crystals obtained from the solution (where the heteropoly compound should have been) did not contain sulfur. On the contrary, the precipitate obtained during the reaction contained sulfur and phosphorus. However, the precipitate had not re-crystallized and had 15 molybdenum groups for every phosphorus atom. A fully saturated heteropoly compound typically contains 12 groups per atom, which is slightly more than this amount. There were twice as many molybdenum molecules as sulfur molecules. The precipitate likely had the compound $H_7(P(Mo_2O_3S_4)*nH_2O)$ in it, along with the heteropoly compound and extra molybdenum trisulfide of that type.

After getting the normal thiocompounds, a solutions for potentiometric titration and other studies were prepared. The pH-metric titration of thio compounds were also attempted. The pH-metric titration of thio compounds, pH-metric titration of the thiosalts of tungsten and molybdenum were also analysed. For this purpose, specially synthesized thio compounds were titrated with hydrochloric acid under standard laboratory conditions. Apparently, as in the case of tungstates and molybdates, when a certain pH is established, the reaction in the solution should proceed according to the equation:

$$x/(NH_4)_2O(MoO_3)/+nHCl = n(NH_4)Cl + (x-n/2)/(NH_4)_2O/xMoO_3 + n/2H_2O$$

The sole distinction between these compounds is the substitution of a sulfur ion for oxygen.

$$x/(NH_4)_2O(MoO_3)/+nHCl= (NH_4)Cl + (x-n/2)/(NH_4)_2SxMoS_3/+n/2H_2S$$

The formation of hydrogen sulfide during the reaction does not allow titration to be carried out in the usual way, since the pH of the solution changes for quite a long time due to the evaporation of H_2S from the solution and the resulting decrease in the concentration of hydrogen ions:

$$2H^+ + S^{2-} = H_2S$$

Therefore, pH-metric titration of thiosalts was carried out in the same way as in the case of tungstates and molybdates, using the “static” method; only in the case of thiosalts was it necessary to prepare less concentrated solutions and to take not 5 but 25 millilitres for titration. Thus, titration curves were obtained similar to the curves obtained earlier for tungstates and molybdates (Figure 1).

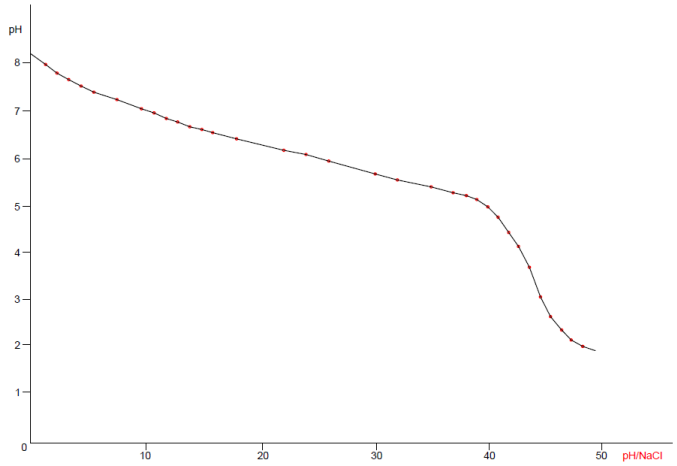

Figure 1. Titration of $(NH_4)_3MoS_3$

As in the case of ordinary tungsten and molybdenum compounds, the graph in pH-amount of added acid coordinates has only one inflexion and in pH-lg v coordinates, the curve is divided into several straight-line segments.

In this case, the solution not only undergoes reaction 1, but also achieves equilibrium:

$$[(NH_4)_2S{\cdot}MoS_3] + 4O^{2-} = [(NH_4)_2O{\cdot}MoO_3] + 4S^{2-}$$

Acidification will cause the equilibrium to move rightward owing to the elimination of the S^{2-} ion as a gas (H_2S).

This procedure necessitates increased acid intake, hence skewing the titration results. Nonetheless, it is essential to acknowledge that this process may occur in several ways and is contingent upon numerous experimental variables, including the concentration of the reactants. For example, progressive acidification to pH 7 may provide a red-brown precipitate indicative of thio parasole, while more acidification to pH 2.7 liberates MoS.

Operating in an acidic environment suggests that oxysulfides are generated concurrently with a lack of 52 ions. The specified location fails to elucidate the interpretation of results derived by titrating thio salts with mineral acid.

Titration cannot elucidate the composition of the compounds; nonetheless, it is certain that molybdenum and tungsten thio salts, like other salts of these elements, will exhibit varying polymeric compounds contingent upon the pH, as seen by the discontinuities in the curve in Figure 1. The “static” pH-metric titration approach revealed the existence of diverse tungsten and molybdenum compounds at varying acidity levels.

The reaction mechanism of the interaction of tungstate and molybdate ions with sulfur compounds has not yet been sufficiently studied and is of interest from various points of view. In some cases, it is possible to gradually replace oxygen with sulfur in different alkaline tungstates and molybdates. How easy it is to do this depends on the type of cation involved. To identify the nature of the formation of thiosalts, a conductometric study of several systems in isomolar series was carried out. The electrical conductivity using a bridge circuit was measued, following the usual protocol (Šepelák *et al*., 2012).

A drum rheochord, a resistance box and a vessel for measuring electrical conductivity make up the circuit; an oscilloscope serves as a polyindicator (Mobasherpour *et al*., 2007).

3. Results and Discussion

A high vessel constant indicates a significant distance between the electrodes and a narrow cross-section of the tube. This enables the most precise measurement of the solutions. The vessel's constancy by measuring the resistance IH of a potassium chloride solution was determined. The electrical conductivity of this solution was measured in standard containers and determined to be 0.11574 Ohm^{-3} cm^{-3} at 27°C. The studies were conducted in a thermostat at a temperature of 30±0.1°C. The research developed an isosmolar series with a total component concentration equivalent to IH (Mollaamin & Monajjemi, 2024). Chemically pure preparations of Na_2WO_4, Na_2MoO_4 and K_2WO_4 were used as starting materials; a precisely measured quantity was extracted from each and IH solutions of the respective salts were formulated. The working mixes by diluting the stock solutions with a 0.5 M sodium carbonate solution was formulated. The concentrations of sodium sulfide and potassium sulfide were ascertained by titration with iodine hyposulfite. The ratios of tungsten or molybdenum to sulfur in all examined systems were: 0.11, 0.25, 0.42, 0.66, 1, 1.5, 2, 3.3, 4 and 9.

Table 3. The electrical conductivity of sodium tungsten

Elec. Conduc	**Cons. H**									
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
X_1	0.0655	0.0684	0.0729	0.0786	0.0820	0.0843	0.0871	0.0935	0.0960	0.0969
X_2	0.0725	0.0824	0.0938	0.1056	0.1142	0.1243	0.1337	0.1425	0.1520	0.1590
$X_3^{x)}$	0.1039	0.1088	0.1202	0.1231	0.1237	0.1339	0.1394	0.1435	0.1524	

Note: X_1 represents the electrical conductivity of sodium molybdate; X_2 denotes the electrical conductivity of sodium sulfide; X_3 signifies the electrical conductivity of mixtures.

The curve Δx shows negative values throughout, the deviations in magnitude are minor and the minimum on the curve cannot be distinguished.

$$Na_2MoO_4 – Na_2S – Na_2CO_3 – H_2O$$

The methodology for quantifying and formulating the system's solutions parallels the description above. The cumulative concentration of sodium molybdate and sodium sulfide in the series is IH. The experimental findings are shown in Table 3. Figure 5 illustrates that the electrical conductivity curve of the combinations converges towards additive values. The curve Δx for the values is negative and lacks a minimum point. Deviations from additivity indicate the chemical nature of interactions within the systems. Assuming the established mechanism of contact by reaction.

$$Na_2WO_4 + 4Na_2S + 4H_2O = Na_2WS_4 + 8NaOH$$

After the reaction, a surplus of hydroxyl ions is generated, which is expected to significantly enhance the solution's electrical conductivity due to the increased mobility of these ions. In this instance, the deviations on the curve Δx must be positive. Negative

deviations on the curves Δx (Figures 2 and 3) suggest the potential creation of weakly dissociated compounds; nevertheless, the consistent nature of these deviations precludes the identification of a single chemical.

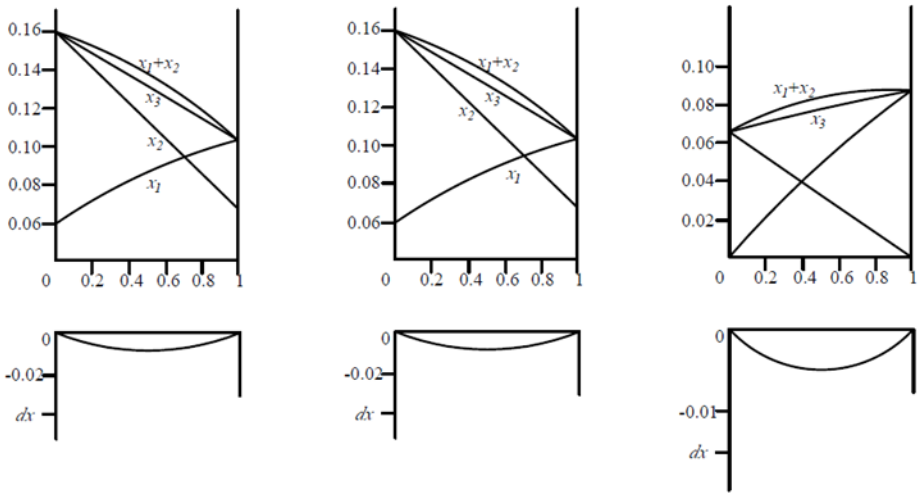

Figure 2. x_1-electrical conductivity of sodium molybdate, x_2 x_2-electrical conductivity of sodium sulfide, x_z – x_z-electrical conductivity of mixtures

In this connection, the dissociation degree of the previously synthesized ammonium tetrathiomolybdate $(NH_4)_2MoS_4$ was determined. The dissociation degree was calculated by the equation $\alpha=\lambda/\lambda_\infty$, where $\lambda = V/100 \cdot \nu$- dilution; λ - equivalent electrical conductivity; λ_∞ - conductivity at infinite dilution.

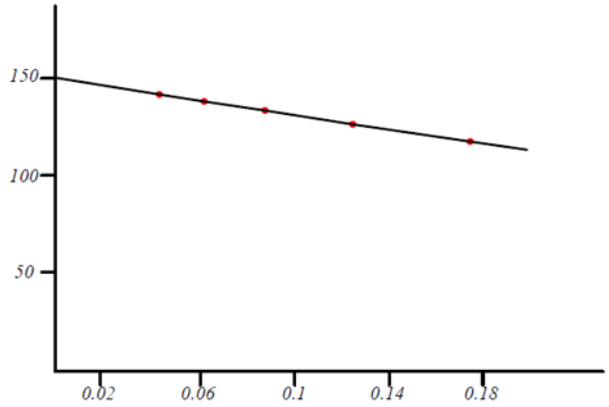

Figure 3. Sulfur concentration

The specific electrical conductivity of an ammonium tetrathiomolybdate solution at 30°C with concentrations of 1/32, 1/64, 1/128, 1/256 and 1/512 H were measured.

Table 4 presents the results of the measurements and calculations. Figure 3 shows a graph for determining the electrical conductivity at infinite dilution.

It can be seen from Table 3 that the degree of dissociation of a 1/32 H solution of $(NH_4)_2MoS_4$ is small. With increasing concentration, the degree of dissociation decreases and this can explain the negative values.

It is known that the whole set of thio salts could only be made with potassium tungstate. Because of this, the K_2WO_4-K_2S-H_2O system was looked into more. The K_2S solution was prepared by saturating a 25% KOH solution with hydrogen sulfide. The sulfur concentration was determined by titration.

Table 4. The degree of dissociation of ammonium molybdate in a soda solution

Concentration C, g/eq/l.	$\sqrt{c}$	**Specific electrical conductivity x, om $^{-1}$ om^{-1}**	**Equivalent conductivity om^{-2} om^{-1} g ekv^{-1}**	**Degree of dissociation - ∞**
1/10	0.330±0.009	10.39x10^{-3}±0.09	103.900±2.09	0.702±0.14
1/32	0.176±0.005	37.99x10^{-4}±0.23	121.568±2.19	0.821±0.15
1/64	0.125±0.004	20.09x10^{-4}±0.19	128.576±2.24	0.868±0.16
1/128	0.088±0.002	10.61x10^{-4}±0.09	135.808±2.45	0.917±0.18
1/256	0.062±0.001	5.42x x10^{-4}±0.04	138.854±2.59	0.938±0.19
1/512	0.044±0.001	2.84x 10^{-4}±0.02	145.408±3.02	0.982±0.19

From the graph λ_∞=148.

The results of calculating the degree of dissociation of ammonium molybdate in a soda solution are given in Table 5.

Table 5. The degree of dissociation of ammonium molybdate in a soda solution

Concentration H	Electrical conductivity x, ом$^{-1}$ ом$^{-1}$	Dilution	Equivalent conductivity Om^{-2} Om^{-1} g ekv^{-1}	Degree of dissociation ∞
0.2	0.0053±0.0002	10	53.50±0.05	0.361±0.005
0.3	0.0128±0.0003	3.33	41.62±0.03	0.281±0.005
0.5	0.0218±0.0003	2	43.78±0.03	0.295±0.004
1	0.0367±0.0004	1	36.75±0.04	0.248±0.004

On the deviation curve from additive electrolysis, two distinct peaks are observed: at p. 0.5NW and 0.5NS, with a 2.0 ratio of W:S=I: I and at p.2 with a concentration ratio of 0.2NW and 0.8NS, where W:5=1:4.

It is plausible that the chemicals K_2WO_3S and K_2WS_4 are synthesized.

The electrical conductivity method fails to detect the replacement of oxygen atoms in tungsten or molybdenum compounds during the formation of thio compounds when reactants are abundant in solution. The increase in electrical conductivity of solutions resulting from the synthesis of thio compounds is offset by a reduction in overall electrical conductivity owing to decreased salt dissociation.

SPA JSC Almalyk MMC obtains solutions containing 0.5 to 5 g/l of molybdenum by the processes of fusing trash with nitrate or leaching it with soda-viticlav.

In the prior study, demonstrated that molybdenum trisulfide could be spontaneously extracted from sodium tungstate solutions using the precipitation method, utilizing nitric acid.

Experiments on purifying actual sodium tungstate solutions demonstrated that the process is successful when the molybdenum concentration exceeds 0.8 g/l. Despite heightened reagent consumption, we could not get adequate cleaning at a reduced concentration. Another alternative for molybdenum cleaning solutions is available in the shop process chain - the crystallization of ammonium paratungstate. This method attains

good purification only if it evaporates no more than 60% of the original volume. In this scenario, mother liquors enriched with molybdenum are generated, which must be extracted from the process after many cycles due to their high molybdenum content.

Upon thorough consideration, it is evident that the molybdenum cleaning procedure is most appropriately integrated into the technological chain during the processing of mother liquors derived from the crystallization of ammonium paratungstate. The primary benefit of this solution is the elimination of the need to clean all process solutions, resulting in a substantial reduction in the volumes requiring cleaning and an enhancement in cleaning quality, particularly when dealing with solutions containing significant amounts of molybdenum.

Initial experiments using established techniques for the direct separation of tungsten and molybdenum present in the mother liquor, however, did not provide the anticipated results. Consequently, it was imperative to devise a suitable technology.

The following aspects throughout the technology development process was evaluated in the mother liquors, tungsten and molybdenum exist as paratungstate and paramolybdate ions, respectively. The synthesis of thio compounds, characterized by the substitution of oxygen with sulfur, does not occur in the same manner as it does in an alkaline medium with standard salt ions. This indicates that the release of trisulfide or any oxysulfides occurs differently, with a significant amount of molybdenum remaining in the solution, rendering purification ineffective. Furthermore, when the mother liquors containing ammonium ions are rendered more acidic, researchers anticipate the formation of tungsten and molybdenum tetrasalts, complicating the separation of these elements.

To effectively isolate tungsten and molybdenum via the optimal trisulfide approach, the mother liquor needed to be transformed into a solution similar to the original. This may be accomplished by fusion or soda-autoclave leaching. It was essential to convert the ammonium salts of tungsten and molybdenum in the mother liquor into sodium salts.

It is significant that, in addition to achieving a purification level over 99%, instances of very inferior purification at just 85-90% also exist. It was observed that the worst quality of purification arises in mother liquors that have been stagnant for an extended period, resulting in precipitation. Solutions that did not exhibit precipitation were purified to a far greater extent, achieving a purity level above 99%. To prevent unwanted rainfall in the future, it was suggested to add alkaline reagents into the mother liquors immediately post-filtration.

All four variations attained adequate purification, as previously noted; nonetheless, manufacturing should endorse the variant using soda.

This variation is distinct from others as it yields the minimal dilution of the original solutions and employs the most economical reagents.

The acidic solution derived from the separation of Mo trisulfide has a blue-brown hue. The colouration results from the presence of decreased tungsten species in the solution. Upon decomposition, sodium tetrathiomolybdate emits hydrogen sulfide and decreases some tungsten compounds. The boiling of acidic pulp generates metasals, which partly diminish the tungsten in the solution. The highly soluble salt, sodium metatungstate, induces tungsten loss during subsequent solution processing. It is not caused by calcium. The acidic solution with a caustic soda solution to revert the metasalt to its original state was heated up.

$$Na_2W_4O_{13} + 6NaOH = 4Na_2WO_4 + 3H_2O$$

Upon boiling the solution, pentavalent tungsten is oxidized to hexavalent tungsten (Zhang *et al*., 2018).

At NMMP, The hydrochloric acid solution using a sodium hydroxide solution with a concentration of 500 g/l to 1.5-2 g/l was neutralized. The solution is subjected to boiling with live steam for 30 minutes, resulting in clarification and the complete conversion of tungsten into normal tungstate. At the firm SPA JSC Almalyk MMC, mother liquors after nBa crystallization underwent sulfide purification to remove Mo. Following the separation of the sulfide precipitate, the colored acidic solution was neutralized with soda ash. An excess of soda was introduced and the solution was subjected to boiling with live steam; nevertheless, this approach failed to clarify the solution. Many clarifying tests on analogous fake solutions in a laboratory setting were performed. Artificial solutions were developed as outlined below: The technical nBa, when combined with ammonium molybdate, was degraded using concentrated solutions.

At the SPA Almalyk MMC enterprise, a scaled-down version of the process for crystallizing ammonium paratungstate from molybdenum to purify mother liquors was used. The experiments undertaken validated the efficacy of the devised approach. The procedure for refining sodium tungstate solution from molybdenum was subjected to industrial evaluation, yielding the following findings. At SPA Almalyk MMC, several tests were conducted. We structured the precipitation portion as follows: her liquors crystallized after nBa.

The precipitation part was designed as follows: formulated the solution and conducted the sedimentation in a stainless steel reactor (García-Domínguez *et al*., 2024). An automated pH meter sensor with a capacity of 20 m^3 was installed in the top section of the reactor, while a parallel left heated and agitated the reactor's contents (Antipova *et al*., 2004). A frame filter press was used to filter the pulp and the filtrate was then transferred to a second 20-cubic-meter reactor for clarifying. Ultimately, a reactor for MoS_3 reprecipitation and a filter press for In the first test, 10 m^3 of mother liquor with a pH of 7.4, including 72 g/l of WO_3 and 10.4 g/l of Mo, was heated to 950°C. Subsequently, calcined soda was introduced at a ratio of 120% for reaction with WO_3, equating to 0.5 kilogram of Na_2CO_3 for every 1 kg of WO_3. In the first experiment involving the precipitation of 10 m^3 of mother liquor with a pH of 7.2 and 10.4 g/l of Mo, the solution was heated to 950°C, followed by the addition of calcined soda at a rate of 0.5 kg Na_2CO_3 per 1 kilogram of WO_3. For 120 kg of WO_3 in solution, 360 kg of soda is necessary; two bags of 33 kilograms each were used.

Following one hour of agitation, the pH increased to 8.4. Subsequently, introduced the sodium sulfide solution. The consumption of 25 corresponds to 200% for the reaction with Mo, namely 6.5 kilograms of Na_2S for 1 kg of Mo; hence, 676 kg of Na_2S is necessary for 104 kg of Mo in solution. 2.8 m^3 of solution containing 242 g/l of Na_2S was added. The resolution remained unchanged. We agitated the fluid while sustaining consistent heating for 30 minutes. We used nitric acid in a 1:1.5 ratio for acidification. The second precipitation was conducted using the mother liquor, which had been held in the workshop for an extended period and had a significant concentration of nBa. The solution was established using WO_3 at 69 g/l and MoO_3 at 24 g/l. The calculation (-0.9)·100/10.4 yields 91.3%. The second precipitation was conducted from the mother liquor, which had been held in the workshop for an extended period. It included a significant concentration of nBa in the settling solution. This was introduced into the reactor. The solution contains a total of 414 kg of WO_3, 144 kg of Mo and requires 207 kg of soda. Seven bags were added and the solution was heated while stirring. A solution

of Na_2S is added in the necessary volume (dry Na_2S needed is 936 kg) (Nimchik *et al*., 2024) the solution is agitated, resulting in a pH of 8.7. Subsequently, we acidified the solution to a pH of 2.5, subjected it to boiling and performed filtration.

The content of molybdenum in the filtrate was 6.4 g/l. Consequently, purification was calculated as ((24 - 6.4) · 100) / 24 = 73.8%. During the acidification step, significant foaming develops, potentially resulting in the ejection of the solution; hence, the use of live steam for stirring is inadvisable. The use of a paraleft results in inadequate mixing and significantly dilutes the solution with condensate. The failure in the second scenario results from the dissolving of nBa in the sediment, which occurred with the addition of the Na_2S solution. This computation was only predicated on the molybdenum concentrations in the solution.

The established research approach permits. Utilizing this approach, they successfully purified mother liquors derived from molybdenum and produced commercial tungsten anhydride that complied with all technical specifications.

4. Conclusion

In conclusion, the study of systems via the electrical conductivity method yields the following finding: the substitution of oxygen atoms in tungsten or molybdenum compounds (formation of thio compounds) at high reactant concentrations (in solution) is not detected by the electrical conductivity method, as the increase in electrical conductivity from the formation of thio compounds is overshadowed by a reduction in the overall electrical conductivity of the solution due to decreased salt dissociation. Experiments on the purification of actual sodium tungstate solutions indicate that the approach is successful when the molybdenum level exceeds 0.8 g/l. Notwithstanding the heightened use of reagents, we failed to get adequate purification at a reduced concentration. It is essential to acknowledge that within the technical process of the shop, there exists an alternative method for purifying solutions from molybdenum - the crystallization of ammonium paratungstate. This procedure attains good purification only if the evaporation process does not exceed 60% of the starting volume. In this instance, mother liquors enriched with molybdenum are generated, which must be extracted from the process after many cycles due to their substantial molybdenum content.

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