Mineral extraction methods based on physical or chemical processes eliminate laborious and dangerous aspects of mining, permit surface control of the mining processes and their complete automation, and eliminate shaft construction and operation and, in some cases, the preparation of the ore in plants.

Physicochemical mining methods are based on removal of the minerals via boreholes drilled from the surface to the ore beds so that the latter can be attacked by appropriate agents. The principal physicochemical methods of extracting a solid component are of course leaching, underground fusion and underground gasification (sublimation) of the minerals.

The principal industrial chemicals (sulfur, crude halides, phosphorites, borates, etc.) are suitable objects for physicochemical mining methods. The range of such products will undoubtedly be extended as progress is made.

Below we will show the effectiveness of physicochemical mining methods by way of examples of several minerals.

Sulfur. Native sulfur serves as the principal source of elemental sulfur in the USSR. The main difficulty in mining sulfur deposits is the selection of an economic method of working deep seams. According to Gosgorkhimproekt, open-cut mines are efficient at depths up to 100-125 m; at greater depths the underground method is preferable. But underground extraction of sulfur (for example, in the Gaudak deposit in Turmeniya) is 2 to 3 times more costly than that of ferrous and nonferrous metals under similar conditions. This is due to difficulties associated with complex hydrologic conditions, the increased hazard of dust explosions or fire during drilling and shotfiring, contamination of the pit air by noxious gases, adverse effects of the underground water, etc. Furthermore, preparation of sulfur ore (flotation beneficiation and autoclave fusion) is both inefficient and expensive.

Shaftless mining of sulfur from deep horizons, based on fusibility of sulfur at relatively low temperatures (112-119°C), seems very promising.

The scheme for underground melting of sulfur by hot water is simple. Three concentric metal pipes of diameters 200, 100, and 33 mm are lowered down a borehole drilled from the surface to the floor of the sulfur-bearing seam. The lower part of the outer pipe is perforated and is separated by a diaphragm. Purified hot water (165°C) is pumped into the space between the outer and middle pipes, passes through the perforated pipe into the seam and melts the sulfur.

The molten sulfur runs into the bottom of the borehole and passes into a receiver, where it is emulsified by compressed air pumped via the inner pipe, and fed to the surface via the annulus between the two smaller pipes. As the sulfur melts, the hot water spreads across the bed and displaces the cold water present, which is fed to the surface via special boreholes.

This is the method employed in sulfur deposits in the littoral belt of the Gulf of Mexico. Experience gained in these deposits has shown that efficient operation requires the following: large reserves of sulfur; considerable seam thickness; sulfur content in the ore more than 18%; seam roof and floor permeable to water; the seam must have some porosity and adequate uniformity, without faults; the site must have reserves of water, fuel, and electricity. If these conditions are present, a "natural autoclave" can be established underground, and the necessary circulation of water and molten sulfur through the seam obtained.
The mode of occurrence of Soviet sulfur deposits is somewhat different. It would therefore be premature to make specific recommendations for mining sulfur by underground fusion.

To determine the technical and economic desirability of mining sulfur by underground fusion in Soviet deposits, we must not only analyze the specific conditions of sulfur deposits but also make a detailed study of the particular features of the mining technology involved. This requires extensive laboratory and industrial experiments on the physical properties of sulfur ores and the adjoining rock, the temperature conditions of fusion of ores with different sulfur contents and structural characteristics, the effect of seam water on temperature conditions, water-heating methods (direct heating in the borehole itself is practicable in some cases), the location and parameters of extraction boreholes.

Research should also be carried out on underground fusion of sulfur by hf currents, and extraction of sulfur by solvents or by partial combustion.

Halides. Underground leaching of salts is common mining practice. In the shaftless method of extraction, boreholes are sunk from the surface. Hot, purified water is pumped into the salt bed and dissolves it, the solution thus obtained being fed to the surface by hydrostatic pressure.

Other well-known methods of working rock-salt deposits by underground leaching are hydraulic cutting, extraction of brines by systems of boreholes, the "battery" method, etc.

There is now a need for an efficient method for underground extraction of potash deposits. Earlier research in this field by Professor P. I. Preobrazhenskii in 1925, E. P. Akhumov in 1936, and A. E. Khod'kov and Yu. V. Morachevskii in 1944-1945 (these two authors studied leaching of carnallites) did not have much practical success, owing to the fact that the solutions were saturated far more rapidly with rock salt than with the accompanying carnallite.

In recent years research and practical work have been carried out in the USA, Canada, and the USSR (Institute of Halurgy) to find ways of mining potash deposits by means of boreholes. In Saskatchewan and installation for underground leaching of potash salts (capacity 600,000 tons per annum) has been erected. To leach sylvite, a weak solution of KCl and NaCl is heated to 45°C and fed via boreholes. The commercial content of the solution discharged from the hole is ~ 200 kg KCl and ~ 300 kg NaCl per m³ water. The salts are extracted from the cooled solution.

Leaching is considered as the most economic method of working potash deposits deeper than 1000 m. But reagents must be found which will get carnallites into solution more rapidly and prevent dissolving of rock salt; efforts must also be made to develop systems and methods of working potash deposits, efficient methods of extracting salts from solutions, etc.

Borehole extraction of carnallites is one of the most promising fields of application of chemistry in mining.

Phosphorites. Several proposals have been made for extracting friable inundated ores by pumping them out via boreholes.

Since 1964 GIGKhS, together with the Phosphorit group and Gosgorkhimproekt, have been studying stripless hydraulic extraction of friable, inundated phosphorite sands.

Experimental work was begun at the Kingisepp site of the Phosphorit group, where a seam of friable phosphorite sand (thickness 3-4 m) is worked; this lies under 10-30 m of hard limestone. The sands have a predominance of medium grains (81% in the range 0.25-0.5 mm), and there are no clay fractions in the ore.

The method is based on extraction of ore via boreholes drilled from the surface. A unit, consisting of an extraction mechanism (hydroelevator or air lift) and a hydromonitor, is introduced into the borehole. A jet of water from the hydromonitor breaks up the solid ore and flushes the product into the borehole, where it is then fed to the surface.

Research has shown that hydraulic extraction of ore via boreholes is a practical method. By reducing the distance between the boreholes and increasing the flow rate and head of the feed water, reliable extraction of ore is obtained, but sometimes at the expense of efficiency and economy. It has also been established that greater amounts of ore cannot be obtained from a single borehole without additional hydromonitor flushing.