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THE RELATIONSHIP OF THE PHYSICAL PROPERTIES OF METAL ELEMENTS WITH THE DEBYE TEMPERATURE

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Abstract. The article describes the interconnection between the metal elements physical properties and Debye temperature. The interrelation between the average temperature coefficient of linear expansion of metals and Debye temperature of an alkali metal is studied. These values are valid for the temperature range from 0 to 100°C. The dependence of the atomization energy of the crystals of the s-elements of groups I, II on Debye temperature of the metal is determined experimentally. The dependence of the sublimation energy of metals on Debye temperature for metals is described. The obtained correlation curves make it possible to characterize more fully the interrelation of the parameter under consideration and the values mentioned above.

Keywords: *Debye temperature, atomic radius, atomic volume, temperature coefficient, atomization energy, sublimation energy.*

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1. Introduction

The technosphere is a part of the biosphere that has undergone changes because of the human activity. The technosphere has an artificial origin as it was created by human beings (Shachneva & Khentov, 2016). The impact of mankind on nature is enormous. The consequences of this influence are not always beneficial to humans. In this regards physicochemical problems of the environment should be outspoken. As a result of human activity and the development of technological processes, including using the latest scientific developments, a huge amount of technogenic waste has appeared. The content of metal elements in the waste is comparable to mineral deposits ones. Therefore, the industrialized society has faced the problem of developing waste processing technology.

As a result of evolutionary processes in nature, an equilibrium in the distribution of chemical elements has been developed. It can be breached mainly because of human activities. An important role is played by the transfer of matter. The transfer phenomenon is associated with non-equilibrium processes. Such processes are considered as a sequence of states. Moreover, not all the states within this sequence are at the equilibrium. Therefore, the system parameters must be changed during a certain period of time. This is possible due to the occurrence of flows associated with the transfer of heat, mass, electric charge, etc. Such processes, leading the system to an equilibrium state, are called transport phenomena.

When studying the demonstration of the physical properties of metal elements, it is important to find one parameter that affects the physical properties. Debye temperature of the chemical element is turned out to be such a parameter. This is an important integral parameter of a solid. The most important physical properties of crystalline substances are associated with the Debye temperature (Vernadsky, 2004; Khentov & Zaitsev, 2002; Khentov *et al.*, 2005).

Previously, for alkali and alkaline earth metals (Khentov & Gasanov, 2015), the interconnection of density, melting point, melting enthalpy, boiling point, vaporization enthalpy, heat capacity, binding energy of elements, coefficient of linear thermal expansion, compressibility coefficient, volume modulus of elasticity, Young's modulus of elasticity, hardness on the mineralogical scale, surface tension was noted , lattice parameter, internuclear distance, crystal lattice energy, electron work function, Fermi energy, atomic concentration, and ionization energy with Debye temperature of the chemical element was described (Meier, 1978). These bonds can also include atomic-ionic radii of alkali and alkaline earth metals (Meier, 1978).

2. Research methods

The experimental part was processed by the method of dispersive, correlation and multiple regression analysis with the exception of insignificant members of the regression equations (Shachneva *et al.*, 2019; Khentov *et al.*, 2019; Khentov & Khussein, 2016; Shachneva & Khentov, 2020). The reliability of the multiple regression equations parameters was checked by dispersive analysis and the Student's criterion (Dospekhov, 1985).

3. The discussion of the results

Figure 1 (Livshic *et al.*, 1980) shows obtained during the study dependence results of the atomic-ionic radius of s-elements of group II on Debye temperature of the metal.

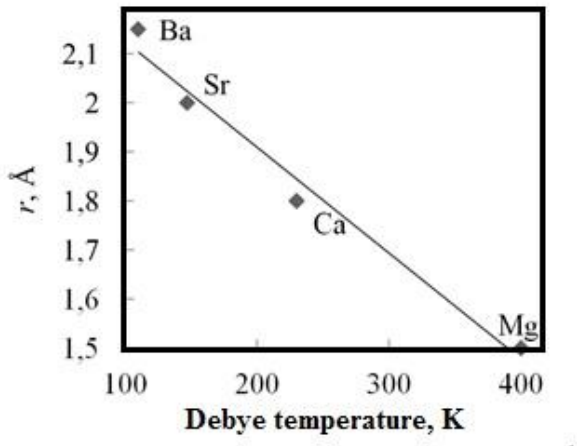

Fig. 1. The dependence of the atomic-ionic radius *r* s-elements of group II on Debye temperature of the metal. The correlation coefficient is 0.989

The atomic volume depends on Debye temperature of an alkaline earth metal (Livshic *et al.*, 1980) (Fig. 2).

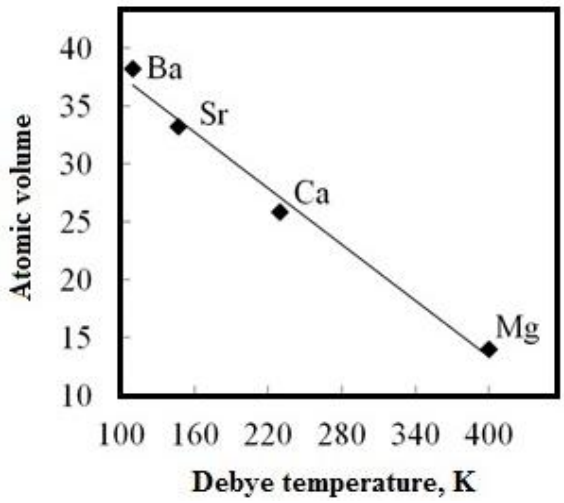

Fig. 2. The dependence of the atomic volume on Debye temperature of the metal. Correlation coefficient 0.993

The average temperature coefficient of linear expansion of metals $\alpha \cdot 10^6$ K^{-1}(at temperatures from 0 to 100°C) (Vainshtein *et al.*, 1979) is reliably associated with Debye temperature of an alkali metal (Fig. 3).

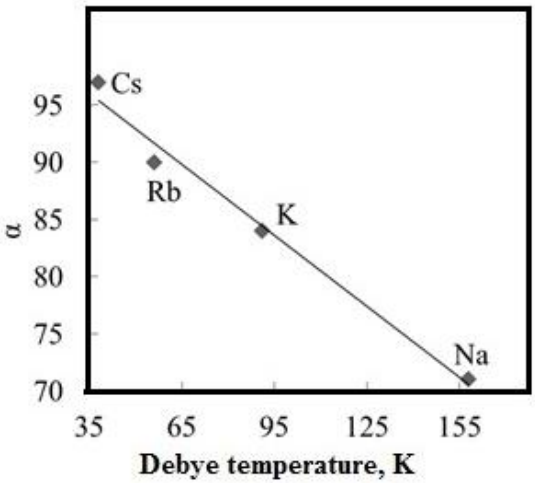

Fig. 3. The dependence of the average temperature coefficient of linear expansion of metals α on Debye temperature of the metal. Correlation coefficient 0.992

The experimentally found atomization energy of crystals *U* of s-elements of groups I and II (Kotrechko & Meshkov, 2007) (Fig. 4) also depends on Debye temperature of the metal (Fig. 4).

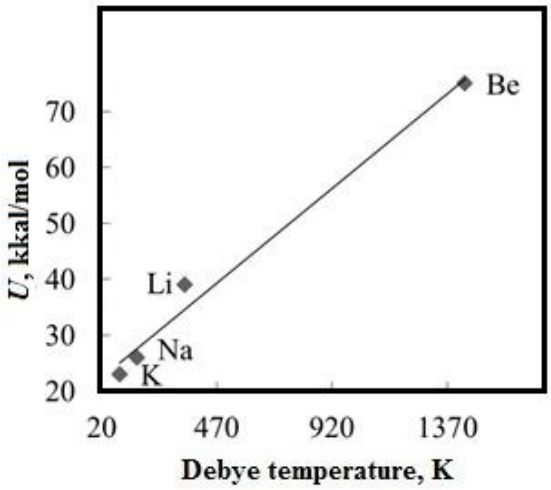

Fig. 4. Dependence of the atomization energy of crystals *U* of s-elements of groups I and II on Debye temperature of the metal. Correlation coefficient 0.992.

The energy of sublimation of metals Q_{subl} is also associated with Debye temperature (Kotrechko & Meshkov, 2007) (Fig. 5).

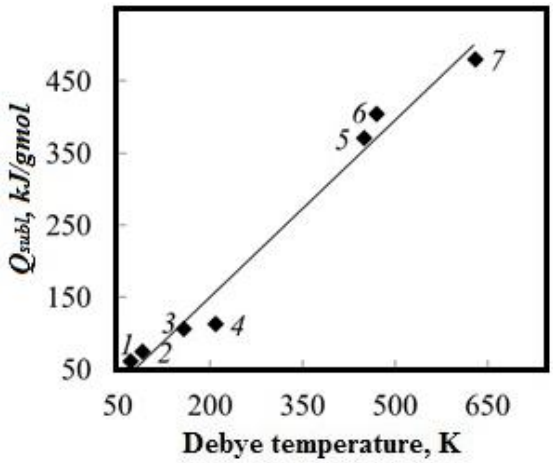

Fig. 5. Dependence of the sublimation energy of metals Q_{subl} on Debye temperature of the metal. *1* – Hg, *2* – K, *3* – Na, *4* – Cd, *5* – Ni, *6* – Fe, *7* – Cr. Correlation coefficient 0.987

Thus, it has been shown that a number of important physicochemical parameters of the crystals of metal elements are reliably determined by Debye temperature. This will make it possible to predict possible physical and chemical environmental problems, and the impact of industrial and agricultural human activities on the atmosphere, hydrosphere and lithosphere, which will serve as a push for the creation of new high-tech technologies without serious consequences for human beings and nature. This is especially important when studying the problem of recycling elements or recycling metals.

4. Conclusion

Summing up all of the above the following conclusion may be drawn. The process describing the dependence of Debye temperature on parameters such as atomic radius, atomic volume, temperature coefficient, atomization energy and sublimation energy, is very complex. That fact is of undoubted interest for the research.

The data obtained in the course of the research indicate that the received values are valid for the temperature range from 0 to 100°C that makes it possible to fully characterize the relationship between the considered parameter and the values above.

Debye temperature of chemical elements is an important integral parameter of a solid that allows to characterize the physical properties of crystalline substances and, consequently, to predict their possible properties and behavior in the environment as well as to describe the process of substance transfer.

The transfer phenomenon happens constantly. This is a serious problem that must be taken into account. Mechanical processes of substance transfer include mechanical solid grinding and liquid dispersion. However, during mechanical processes of substance dispersion, deep transformations of the substance can occur at the molecular level. This cause significant changes of the physical and chemical properties of the substance. For example, it leads to the changing of melting point and the increasing of substance reactivity. The «dimensional effect» plays an important role here.

When a solid is grinded, shift deformation occurs. It is the simultaneous effect of pressure and mechanical action influence. As a result defects in the crystal lattice appear and accumulate and the reactivity of the solid increases.

The physical and chemical properties of a solid change due to the influence of mechanical processing. All of the described above will allow to assess in details the influence of such parameters as Debye temperature on the critical characteristics of the element which will lead to a deeper consideration of the phenomenon of transfer.

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