

## SURFACE TENSION OF CYCLIC LIQUID HYDROCARBONS

A.S. Alekperov\*, G.G. Mirzayeva

Azerbaijan State Pedagogical University, Baku, Azerbaijan

**Abstract.** The effect of high temperatures on the surface tension of liquid cyclic hydrocarbons has been studied. The studies were carried out in the temperature range  $T = 273-373$  K. The mechanism of change in the coefficient of surface tension of cyclic hydrocarbons depending on temperature was determined. In the course of research, it was found that the processes on the surface of cyclic hydrocarbons depend on their structure. There was a difference in the value of the surface tension coefficient depending on the chemical composition and structure. This difference was also observed in the change in coefficients depending on temperature.

**Keywords:** cyclic hydrocarbons, liquid hydrocarbons, surface tension.

**Corresponding Author:** A.S. Alekperov, Azerbaijan State Pedagogical University, Baku, AZ-1000, Azerbaijan, e-mail: [aydin60@inbox.ru](mailto:aydin60@inbox.ru)

**Received:** 29 September 2022; **Accepted:** 24 November 2022; **Published:** 30 December 2022.

### 1. Introduction

The study of the physical and chemical properties of liquid materials is one of the main areas of molecular physics (Ibrahimli, 2022; Hossain *et al.*, 2022). In the course of research, it was found that the determination of the surface tension and dynamic viscosity of liquids plays an important role in the study of their other physical properties. These properties are widely used in the transportation of liquids (Chappan, 1966; Alder & Wainwright, 1970; Bordat & Muller-Plathe, 2002; Alexandre *et al.*, 2012; Jakse *et al.*, 2011). In addition to experimental studies of liquids, theoretical studies are also carried out. With the help of modern programs, it is possible to study many processes occurring in these materials under external influences (Yang *et al.*, 2010; Maebashi & Takada, 2009).

It is known that the physical properties of liquids, like solids, depend on their structure. Therefore, in addition to liquids of organic materials, the structure and physical properties of liquid states of inorganic materials with ionic bonds are studied. Interesting physical properties were discovered in studies carried out by infrared spectroscopy (Masimov *et al.*, 2017, 2019; Budagov *et al.*, 2017; Alekperov *et al.*, 2019, 2020; Aliyev *et al.*, 2020).

Surface phenomena differ from the processes occurring in the volume. Therefore, interesting results are obtained when studying the surface structure and processes occurring in thin layers (Ahmadova & Jabarov, 2022; Agayev *et al.*, 2020). More interesting are the processes occurring on the surface of liquids. Because surface tension forces are stronger than internal forces. Although the chemical and technical properties

of cyclic and aromatic liquid hydrocarbons have been studied, their physical properties have not been studied enough. In this work, the surface tension of cyclic liquid hydrocarbons was studied. The processes occurring in these liquids at high temperatures are studied.

## 2. Research methods and materials

In this work, the surface tension of cyclic liquid hydrocarbons was studied. Six liquids from the group of pentane and hexane, as well as liquids of ethyl alcohol, acetone, and methyl alcohol were taken as liquid cyclic hydrocarbons from aromatic hydrocarbons. During the study, a new method was used. The new method used general cycles or the thermodynamic potential approach. This method is applicable to all liquids. Because the results obtained in the study of the surface tension of simple liquids by the phenomenological method correspond to the experimental results obtained in the course of previous studies. To determine the temperature dependence of  $\sigma$  and  $q$ , the surface tension of aromatic and cyclic hydrocarbon liquids consisting of polyatomic molecules was studied in the course of research.

## 3. The discussion of the results

Liquid cyclic hydrocarbons are the most studied compounds among organic compounds. Many physical properties of these compounds are known. Some thermal properties of these liquids: melting and boiling points are given in Table 1.

**Table 1.** Thermal parameters of cyclic hydrocarbons

Cyclic hydrocarbons	$T_m, \text{K}$	$T_b, \text{K}$
Cyclopentane ( $\text{C}_5\text{H}_{10}$ )	179.12	322.26
Methylcyclopentane ( $\text{C}_6\text{H}_{12}$ )	130.74	344.84
Cyclohexane ( $\text{C}_6\text{H}_{12}$ )	146.40	353.74
Methylcyclohexane ( $\text{C}_7\text{H}_{14}$ )	399.59	373.93

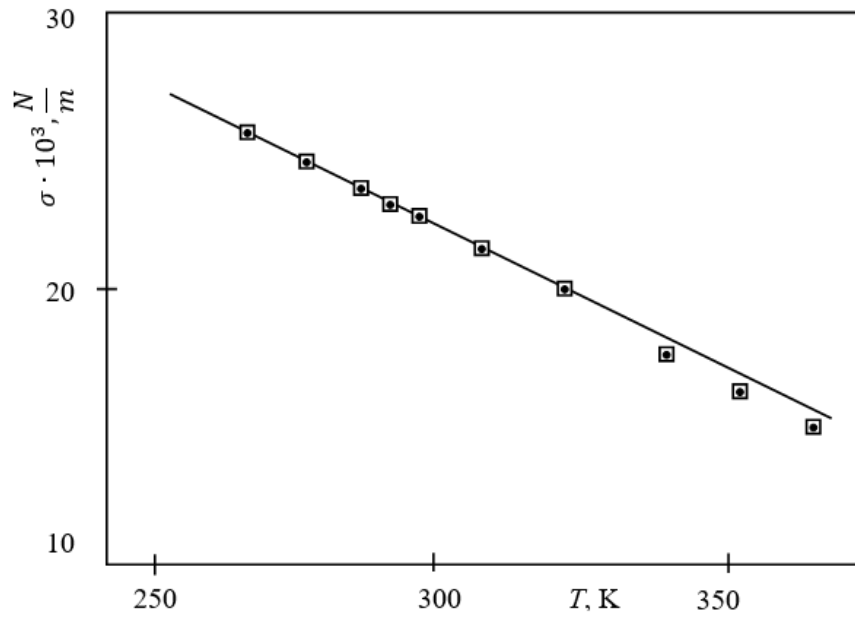
Theoretically, from a phenomenological point of view, the surface tension coefficient of liquid cyclic hydrocarbons has been studied at high temperatures. Temperature ranges are taken from room temperature to melting temperature. The following expressions were used to determine the coefficient of surface tension and surface friction of cyclic liquid hydrocarbons:

$$q(T) = q_0 + \alpha(T - T_m) \quad (1)$$

$$\sigma(T) = [2q_0 + \alpha(T_c + T - 2T_m)] \frac{T_c - T}{T_c + T} \quad (2)$$

where,  $T_m$  is the melting temperature,  $T_c$  is the critical temperature.

When calculating the surface tension of cyclic hydrocarbons, it was found that the surface tension coefficient of pentane and hexanes does not decrease linearly over a wide temperature range. It decreases non-linearly at certain time intervals. On Fig. 1 shows the temperature dependence of the surface tension coefficient of methylcyclohexane.



**Fig. 1.** Temperature dependence of the surface tension coefficient of methylcyclohexane

As can be seen from the dependence shown in Fig. 1, the value of the surface tension coefficient of methylcyclohexane decreased. As the temperature increased, it decreased linearly. However, at temperatures  $T \geq 300$  K, the dependence  $\sigma \approx \sigma(T)$  deviated from linearity. It can be assumed that this effect is associated with a sharper change in the intermolecular distance compared to Hooke's law. For the liquid hydrocarbons cyclohexane ( $\text{C}_6\text{H}_{12}$ ) and methylcyclohexane ( $\text{C}_7\text{H}_{14}$ ), the critical temperature and surface tension coefficient were calculated at several temperatures. The values obtained are shown in Table 2 and Table 3, respectively.

It has been established that in order to characterize the temperature dependence of the surface tension coefficient, it is necessary to determine the dependence  $\sigma = \sigma(T)$ , as well as  $\sigma = f \left[ \frac{T_c - T}{T_c + T} \right]$ . Therefore, these values are defined in Table 2 and Table 3. During the analytical analysis of the obtained results, it was found that the dependence  $\sigma = f \left[ \frac{T_c - T}{T_c + T} \right]$  gives a straight line with a slope equal to  $2q$ . It is known that  $q$  is the coefficient of surface formation and has a physical meaning. Therefore, it is more expedient to present the temperature dependence of the surface tension coefficient in this way.

**Table 2.** Values for the surface tension coefficient of liquid cyclohexane ( $\text{C}_6\text{H}_{12}$ )

$T, \text{K}$	$\frac{T_c - T}{T_c + T}$	$2q \cdot 10^3, \text{N/m}$	$\sigma \cdot 10^3, \text{N/m}$
273	0.339	80.812	26.87
283	0.323	80.960	26.15
293	0.307	81.270	24.95
298	0.300	81.167	24.35
303	0.292	81.336	23.75
313	0.277	81.047	22.45
323	0.263	81.179	21.35
348	0.228	80.482	18.35
373	0.194	80.124	17.22

**Table 3.** Values for the surface tension coefficient of liquid methylcyclohexane (C<sub>7</sub>H<sub>14</sub>)

$T, \text{K}$	$\frac{T_c - T}{T_c + T}$	$2q \cdot 10^3, \text{N/m}$	$\sigma \cdot 10^3, \text{N/m}$
273	0.355	72.67	25.80
283	0.339	72.98	24.74
293	0.323	73.31	23.68
298	0.316	73.26	23.75
303	0.308	73.04	22.62
313	0.295	73.08	21.56
323	0.279	73.47	20.50
348	0.247	72.27	17.85
373	0.211	72.13	15.24

As a result of the analysis, it was found that the surface tension coefficient decreases with increasing temperature in all cases. The surface tension coefficients of liquids belonging to different groups are also different. This feature indicates that the structure of molecules plays an important role in surface tension. From Table. 2 shows that the coefficient of surface tension of liquid cyclohexane under normal conditions ( $T = 273 \text{ K}$ ) is  $\sigma = 26.87 \cdot 10^{-3} \text{ N/m}$ . Depending on the temperature value, the value of the surface tension coefficient decreases and has a value of  $\sigma = 17.22 \cdot 10^{-3} \text{ N/m}$  at a temperature  $T = 373 \text{ K}$ . In the temperature range  $\Delta T = 100 \text{ K}$ , there was a decrease to  $\Delta\sigma = 9.65 \cdot 10^{-3} \text{ N/m}$ . That's a pretty big difference. As can be seen, the surface tension coefficient of cyclohexane changes dramatically with temperature. This effect was also observed in other cyclic hydrocarbons. From Table. 3 shows that the coefficient of surface tension of liquid methylcyclohexane under normal conditions ( $T = 273 \text{ K}$ ) is  $\sigma = 25.80 \cdot 10^{-3} \text{ N/m}$ . Depending on the temperature value, the value of the surface tension coefficient decreases and has the value  $\sigma = 15.24 \cdot 10^{-3} \text{ N/m}$  at a temperature  $T = 373 \text{ K}$ .  $\Delta\sigma = 10.56 \cdot 10^{-3} \text{ N/m}$  decreased in the temperature range  $\Delta T = 100 \text{ K}$ .

As can be seen, the surface tension coefficient of methylcyclohexane is more dependent on temperature than the surface tension coefficient of cyclohexane. This is due to the fact that the surface tension coefficient of cyclic hydrocarbons does not depend only on temperature. It also depends on their structure. The structural change that occurs depending on the concentration of the atoms included in the structure is also manifested in other physical and chemical properties.

#### 4. Conclusion

The surface tension of cyclic liquid hydrocarbons has been studied. It has been established that the coefficient of surface tension of liquid cyclic hydrocarbons included in the group of pentane and hexane corresponds to an analytical expression determined in a wide temperature range where a liquid state of aggregation exists. This expression is the same for every cyclic hydrocarbon group. It has been established that the heat of surface formation of liquid cyclic hydrocarbons does not depend on the type of liquid, and the surface tension is determined by the geometric shape of the liquid molecule. It has been established that using the analytical law established for the surface tension of liquid cyclic hydrocarbons, it is possible to determine the critical temperature of the liquid from the value of the surface tension coefficient at an arbitrary temperature.

## References

- Agayev, F.G., Jabarov, S.H., Ayyubova, G.Sh., Mirzayev, M.N., Trukhanov, S.V., Trukhanova, E.L., Darwish, M.A., Podgornaya, S.V., Vinnik, D.A., Hoang, T.P., Dang, N.T., & Trukhanov, A.V. (2020). Structure and thermal properties of BaFe<sub>11.1</sub>In<sub>0.9</sub>O<sub>19</sub> hexaferrite. *Physica B: Condensed Matter.*, 580, 411772.
- Ahmadova, Kh.N., Jabarov, S.H. (2022). Obtaining Al nanolayers and crystal structure. *International Journal on Technical and Physical Problems of Engineering*, 14(3), 116-120.
- Alder, B.J., Wainwright, T.E. (1970). Decay of the velocity autocorrelation function. *Physical Review A*, 1(1), 18-21.
- Alekperov, A.S., Jabarov, S.H., Mirzayev, M.N., Asgerov, E.B., Ismayilova, N.A., Aliyev, Y.I., Thabethe, T.T., & Dang, N.T. (2019). Effect of gamma irradiation on microstructure of the layered Ge<sub>0.995</sub>Nd<sub>0.005</sub>S. *Modern Physics Letters B*, 33(09), 1950104.
- Alekperov, A.S., Dashdemirov, A.O., Ismayilova, N.A., & Jabarov, S.H. (2020). Fabrication of a Ge-GeS:Nd heterojunction and investigation of the spectral characteristics. *Semiconductors*, 54(11), 1406-1409.
- Alexandre, D., Alexandre, P., & Santos, Y.L. (2012). Surface tension of an electrolyteair interface: a Monte Carlo study. *Journal of Physics: Condensed Matter*, 24, 284115.
- Aliyev, Y.I., Asadov, Y.G., Ilyasli, T.M., Mammadov, F.M., Naghiyev, T.G., Ismayilova, Z.A., Mirzayev, M.N., & Jabarov, S.H. (2020). Structural aspects of thermal properties of AgCuS compound. *Modern Physics Letters B*, 34(05), 2050066.
- Bordat, P., Muller-Plathe, F. (2002). The shear viscosity of molecular fluids: A calculation by reverse nonequilibrium molecular dynamics. *Journal of Chemical Physics*, 116(8), 3362-3369.
- Budagov, K.M., Guseinov, A.G., & Pashaev, B.G. (2017). Mechanism of the emergence of the photo-EMF upon silicon liquid crystal - single crystal contact. *Russian Journal of Physical Chemistry A*, 91(3), 595-598.
- Chappan, N.W. (1966). The viscosity of liquid metals. *American Institute of Chemical Engineers Journal*, 2, 395-400.
- Hossain, M.S., Bitu, N.A., Khan, M.N., Asraf, A., & Hossen, F. (2022). 2, 3-dimethoxybenzaldehyde schiff base of sbdtc and its metal complexes of Ni (II), Cu (II), Zn (II) AND Cd (II): synthesis, characterization and biological activity. *New Materials, Compounds and Applications*, 5(3), 182-191.
- Ibrahimli, A.B. (2021). On a nature of dynamic viscosity in liquid metals. *New Materials, Compounds and Applications*, 5(3), 245-251.
- Jakse, N., Nguyen, T.L., & Pasturel, A. (2011). Ordering effects in disordered systems: the Au-Si system. *Journal of Physics: Condensed Matter.*, 23(40), 404205.
- Maebashi, H., Takada, Y. (2009). First-principles understanding of the anomalous structural change in on expanded liquid alkali metal. *Journal of Physical Society of Japan*, 78(5), 053706.
- Masimov, E.A., Pashayev, B.G., & Hasanov, H.Sh. (2019). Viscometric study of diluted aqueous solutions of polyethylene glycols of different molecular weights. *Russian Journal of Physical Chemistry A*, 93(5), 988-990.
- Masimov, E.A., Pashaev, B.G., & Hasanov, G.Sh. (2017). Structure of aqueous solutions of sucrose, derived from viscosimetry data and IR spectroscopy. *Russian Journal of Physical Chemistry A*, 91(4), 667-671.
- Yang, J., Tse, J.S., & Itaka, T. (2010). First-principles studies of liquid lithium under pressure. *Journal of Physics: Condensed Matter.*, 22(9), 95503.