*Asian Journal of Chemistry* Vol. 6, No. 1 (1994), 125–129

# Molar Sound Velocity and Molar Compressibility of Castor Oil at Elevated Temperature and Pressure

M.C. SAXENA* and SHIPRA SIRCAR
*Chemical Laboratories*
*K.S. Saket Post-Graduate College*
*Faizabad-224 001 India*

Molar sound velocity and molar compressibility have been evaluated in castor oil at wide range of temperature and pressure. Their relations with temperature and pressure have been discussed in the light of Rao and Wada Rule.

## INTRODUCTION

In continuation of our earlier work[1,2], we report in the present paper the calculated value of Rao and Wada constant in case of castor oil, at wide range of temperature and pressure, using sound velocity and density data of Timme[3]. It is found that both sound velocity (Rao constant) R and molar compressibility (Wada constant) W vary with temperature and pressure, showing deviation from Rao and Wada rule in castor oil.

### Theoretical

Molar sound velocity and molar compressibility are of much use in studying the physico-chemical behaviour of liquid and gaseous state of matter. Rao[4,5] has given an empirical relation between temperature coefficient, sound velocity and volume expansion coefficient for many organic liquids, which can be given as:

$$\frac{1}{c}\left(\frac{\partial c}{\partial T}\right)_p = -K\frac{1}{V}\left(\frac{\partial v}{\partial T}\right)_p \tag{1}$$

or

$$\frac{\partial(\rho_n c)}{\partial(\rho_n V)_p} = \frac{V}{c}\left(\frac{\partial c}{\partial V}\right)_p = -\frac{\rho}{c}\left(\frac{\partial c}{\partial \rho}\right)_p = -K \tag{2}$$

On combining equations (1) and (2) we get

$$Vc^{1/k} = R \tag{3}$$

where c is the velocity of sound in liquid, T is temperature, V is molar volume, $\rho = M/V$ and P is pressure. Rao has used the value of K as 3 after studying a number of liquids.

*Madhu Ban, 368–F, Balla Hata, Opposite Sona Biscuit Company, Hospital Road, Faizabad–224 001, India.

On putting value of K as 3 in the equation (3), one obtains,

$$Y = Vc^{1/3}$$

a constant for a particular liquid which is independent of temperature. In a similar way Kornvel and Litovitz[6] gave the following expression:

$$\frac{1}{c}\left(\frac{\partial C}{\partial \rho}\right)_T = -K' \frac{1}{V}\left(\frac{\partial V}{\partial \rho}\right)_T \tag{4}$$

or

$$\frac{\partial (\rho_n c)}{\partial (\rho_n V)_T} = \frac{V}{c}\left(\frac{\partial c}{\partial V}\right)_T = \frac{\rho}{c}\left(\frac{\partial c}{\partial \rho}\right)_T = -K' \tag{5}$$

where K was also taken as 3. These workers obtained

$$R' = Vc^{1/3} \tag{6}$$

again a constant R

Several other workers[7–14] also worked on these relations and principles, theoratically. Experimental work has also been done in this field by several workers[15–17] to find out details. Rao and Rao[18] have also worked on this rule, but the results obtained gave no support to the Rao rule; instead, they supported Kornvel and Lito-vitz rule.

According to Rao and Rao

$$K' = \frac{n + m + 3}{6}$$

It was found that K and K′ depend upon temperature and pressure, and vary with temperature and pressure and their difference can be given by the relation

$$K' - K = \frac{1}{\beta_T} \cdot \frac{1}{c}\left(\frac{\partial c}{\partial \rho}\right)_v \tag{7}$$

where $\beta_T$ is isothermal compressibility. Wada[19] gave a similar expression for adiabatic compressibility as

$$\frac{\frac{1}{\beta_S}\left(\frac{\partial B_S}{\partial T}\right)_p}{\frac{1}{\rho}\left(\frac{\partial \rho}{\partial T}\right)_p} = n_1 \tag{8}$$

and

$$\frac{\frac{1}{B_S}\left(\frac{\partial B_s}{\partial p}\right)_T}{\frac{1}{\rho}\left(\frac{\partial \rho}{\partial p}\right)_T} = n_2 \tag{9}$$

where $n_1$ and $n_2$ are constants, the values of which for almost all organic liquids are 6.5 and 7.3. According to Wada the values for $n_1$ and $n_2$ in above equations are equal and it may be kept as 7. Therefore from above equation we can get

$$V\beta_s^{-1/7} = W \tag{10}$$

where W is known as molar compressibility which is independant of temperature and pressure.

## RESULTS AND DISCUSSION

Several workers[20–25] have made studies in which deviations from Rao, Kornvel, Litovitz and Wada rule have been observed in liquids and liquified gases. In the present paper values of molar sound velocity (Rao constant) R and the molar compressibility (Wada constant) W for castor oil have been calculated using equations (6) and (10) at different temperatures and pressures. The necessary data required for calculations were taken from the literature[3,26]. The results obtained are reported in Table 1.

TABLE 1
MOLAR SOUND VELOCITY (R) AND MOLAR COMPRESSIBILITY (W) FOR CASTOR OIL

| Pressure | Velocity of sound m/s | ρ gm/cc | R | W |
|---|---|---|---|---|
| (Ref-3) | (Ref-3) | (Ref-26) | (Eqn-6) | (Eqn-10) |
| | | T = 273.15 K | | |
| Atmosphere | 1570 | 0.9737 | 3604.80 | 2527.83 |
| 70 MPa | 1791 | 1.0013 | 3662.75 | 2562.63 |
| 80 MPa | 1819 | 1.0046 | 3668.73 | 2566.22 |
| 90 MPa | 1846 | 1.0078 | 3675.08 | 2570.02 |
| 100 MPa | 1871 | 1.0110 | 3679.91 | 2572.92 |
| 110 MPa | 1896 | 1.0141 | 3684.93 | 2575.93 |
| | | T = 278.15 K | | |
| Atmosphere | 1553 | 0.9703 | 3604.33 | 2527.56 |
| 70 MPa | 1776 | 0.9987 | 3661.10 | 2561.64 |
| 80 MPa | 1804 | 1.0021 | 3667.76 | 2565.63 |
| 90 MPa | 1831 | 1.0054 | 3673.85 | 2569.29 |
| 100 MPa | 1857 | 1.0087 | 3679.08 | 2572.42 |
| 110 MPa | 1882 | 1.0118 | 3684.19 | 2575.49 |
| | | T = 283.15 K | | |
| Atmosphere | 1537 | 0.9662 | 3607.15 | 2529.25 |
| 70 MPa | 1761 | 0.9961 | 3660.30 | 2561.15 |
| 80 MPa | 1789 | 0.9997 | 3666.32 | 2564.77 |
| 90 MPa | 1816 | 1.0030 | 3672.56 | 2568.52 |
| 100 MPa | 1842 | 1.0064 | 3677.54 | 2571.49 |
| 110 MPa | 1868 | 1.0096 | 3683.05 | 2574.79 |
| | | T = 288.15 K | | |
| Atmosphere | 1521 | 0.9636 | 3604.29 | 2527.53 |
| 70 MPa | 1746 | 0.9932 | 3660.52 | 2561.29 |
| 80 MPa | 1774 | 0.9951 | 3672.96 | 2568.75 |
| 90 MPa | 1802 | 1.0005 | 3672.25 | 2568.33 |
| 100 MPa | 1828 | 1.0039 | 3677.33 | 2571.37 |
| 110 MPa | 1854 | 1.0073 | 3682.21 | 2574.29 |

| Pressure (Ref-3) | Velocity of sound m/s (Ref-3) | ρ gm/cc (Ref-26) | R (Eqn-6) | W (Eqn-10) |
|---|---|---|---|---|
| | | T = 293.15 K | | |
| Atmosphere | 1505 | 0.9602 | 3604.31 | 2527.54 |
| 70 MPa | 1731 | 0.9907 | 3659.24 | 2560.52 |
| 80 MPa | 1760 | 0.9944 | 3665.85 | 2564.49 |
| 90 MPa | 1788 | 0.9981 | 3671.53 | 2567.89 |
| 100 MPa | 1814 | 1.0016 | 3676.34 | 2570.78 |
| 110 MPa | 1840 | 1.0050 | 3681.33 | 2573.76 |
| | | T = 298.15 K | | |
| Atmosphere | 1490 | 0.9572 | 3603.58 | 2527.10 |
| 70 MPa | 1717 | 0.9881 | 3658.93 | 2560.34 |
| 80 MPa | 1746 | 0.9917 | 3666.06 | 2564.62 |
| 90 MPa | 1774 | 0.9956 | 3671.12 | 2567.65 |
| 100 MPa | 1801 | 0.9997 | 3674.51 | 2569.68 |
| 110 MPa | 1827 | 1.0032 | 3679.23 | 2572.51 |
| | | T = 303.15 K | | |
| Atmosphere | 1474 | 0.9540 | 3602.67 | 2526.56 |
| 70 MPa | 1704 | 0.9857 | 3658.56 | 2560.12 |
| 80 MPa | 1732 | 0.9892 | 3665.48 | 2564.27 |
| 90 MPa | 1761 | 0.9933 | 3670.61 | 2567.34 |
| 100 MPa | 1788 | 0.9970 | 3675.58 | 2570.32 |
| 110 MPa | 1814 | 1.0004 | 3680.75 | 2573.42 |
| | | T = 308.15 K | | |
| Atmosphere | 1460 | 0.9504 | 3604.83 | 2527.86 |
| 70 MPa | 1690 | 0.9831 | 3658.16 | 2559.88 |
| 80 MPa | 1719 | 0.0866 | 3665.92 | 2564.53 |
| 90 MPa | 1747 | 0.9909 | 3669.72 | 2566.81 |
| 100 MPa | 1775 | 0.9946 | 3675.49 | 2570.27 |
| 110 MPa | 1801 | 0.9984 | 3679.30 | 2572.55 |
| | | T = 313.15 K | | |
| Atmosphere | 1445 | 0.9473 | 3604.20 | 2527.48 |
| 70 MPa | 1677 | 0.9806 | 3658.06 | 2559.82 |
| 80 MPa | 1706 | 0.9849 | 3666.32 | 2564.77 |
| 90 MPa | 1735 | 0.9885 | 3670.19 | 2567.09 |
| 100 MPa | 1762 | 0.9923 | 3675.00 | 2569.98 |
| 110 MPa | 1789 | 0.9959 | 3680.32 | 2573.16 |

Table 1 consists of values of molar sound velocity and molar compressibility of castor oil ranging from 273.15 K to 313.15 K at various pressures from atmospheric to 110 MPa. The values of R and W are given in columns four and five.

A perusal of column four and five reveals that there is a regular increase in the values of R and W with increase of pressure. Temperature has no marked effect on the values of R and W, as observed by Rao and Wada.

The molar sound velocity and molar compressibility are pressure dependent values. Their values in case of castor oil increase with pressure at constant temperature. Their values are interrelated with the values of sound velocity and density with increase of pressure.

Finally it may be concluded that molar sound velocity R and molar compressibility W are pressure dependent parameters and the present study shows that Rao and Wada rule are not applicable in case of castor oil at elevated pressure.

## ACKNOWLEDGEMENTS

The authors are grateful to Dr. M.P. Gupta, Head, Department of Chemistry and Shri Y.R. Tripathi, Principal, K.S. Saket P.G. College, Faizabad for providing library facility in the college.

## REFERENCES

1. J.D. Pandey, P. Dubey and M.C. Saxena, *Acustica*, **48**, 277 (1981).
2. M.C. Saxena, *Asian J. Chem.* **5**, 979 (1993).
3. R.W. Timme, *J. Acoust. Soc. Amer.*, **52**, 989 (1972).
4. N.R. Rao, *Indian J. Phys.*, **14**, 109 (1940).
5. N.R. Rao, *J. Chem. Phys.*, **9**, 682 (1941).
6. E.N. Kornvel and T.A. Litovitz, *J. Acoust Soc.*, **27**, 547 (1955).
7. O. Nomoto, *J. Phys. Soc. (Japan)*, 10, 31, 11, 1145 (1955).
8. N.R. Rao, *Indian J. Pure Appl. Phys.*, **3**, 309 (1956).
9. S.S. Mathur, P.N. Gupta and S.S. Sinha, *J. Phys.*, **A4**, 434 (1971).
10. E. Soezkie Wies, *J. Phys.* **A5**, 31, (1972).
11. O.N. Singh, N. Das, & N.C. Varshneya, *J. Phys.*, **A5**, 36 (1972).
12. Schunyer, *J. Polymer Sci.*, **36**, 475 (1959).
13. K.M. Swami and P.S. Swami, *J. Acoust. Soc. India*, **3**, 2330 (1974).
14. R.A. Aziz, D.S. Browman and C.C. Lin, *Can. J. Phys.*, **50**, 546 (1972).
15. R.J. Legman, D.R.J.R. McMulan and W.E. Woolf, *J. Chem., Phys.*, **17**, 369 (1949).
16. P.R.K.L. Padmini and V. Ramchandra, *Trans. Farad. Soc.*, **58**, 650 (1962).
17. P.R.K.L. Padmini, Suka Rao and V.R. Rao, *Trans. Farad. Soc.* **56**, 1404 (1960).
18. R.V.G. Rao and B.S.M. Rao. *Trans. Farad. Soc.*, **62**, 2704 (1966).
19. Y. Wada, *J. Phys. Soc. Japan*, **4**, 280 (1949).
20. V.F. Nazdrev, Application of Ultrasonics in Molecular Physics, Garden and Birrach, New York (1963).
21. Wama Van Dael, Van Ittenbeck, Physics of High Pressure and Condensed Phase, John Wiley and Sons, Inc., New York, P. 350 (1965).
22. K. Samal and A.N. Patnaik, *Indian. J. Pure Appl. Phys.*, **11**, 566 (1973).
23. S. Rajgopalan, *J. Phys. Soc. Jap.*, **25**, 1204 (1968).
24. K.M. Swami, and P.S. Swami, *J. Acoust. Soc. India*, **3**, 23, 30 (1974).
25. V. Tiwari, *Acustica*, **40**, 33 (1978).
26. J.D. Pandey, R.L. Mishra and T. Bhatt, *Acustica*, **38**, 83 (1977).

(Received: 28 December 1992; Accepted: 1 May 1993) AJC–610