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Thermodynamic-Acoustic Studies of Mixture Vitamin B_7 with Glycols at Different Temperatures

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Abstract: The density and speed of sound for an aqueous solution containing Vitamin B_7 (biotin) at variant temperatures from (288.15K to 318.15K) and (0.000 to 0.003) mol·kg^{-1} concentration has been measured with Anton Paar DSA 5000 M at constant pressure 0.1 MPa. The observed data were used to derive various thermo-acoustic parameters. Acoustic impedance, adiabatic compressibility, Vander Waal's constant, Rao's constant, Wada's constant, and intermolecular free length were determined by the obtained speed of sound and density values. In addition, the ternary mixture of biotin and glycols (Propylene glycol and hexylene glycol) shows the intermolecular (solute-solvent) interactions inside the liquid solution.

Keywords: density; intermolecular free length; biotin; hexylene glycol; adiabatic compressibility.

1. Introduction

Ultrasonic studies have become prominent over the last few years in the chemical [1], engineering, and agricultural fields. The ultrasonic technique is a powerful tool as it gives information about the intermolecular interactions between the solute-solvent or solvent-solvent mixture. Ultrasonic velocity is very helpful in understanding the thermo-acoustic properties and molecular interaction in an aqueous solution [2,3]. The liquid state is the most widely used among the three states due to its simplicity and accuracy. The ultrasonic technique is used to detect flaws, characterize the material, and measure dimensions in liquid mixture, [4] polymeric solution. The ultrasonic technique is an NDT (Non-Destructive Technique) [5] that cannot cause any damage or disorder to the structure and does not change the sample. It is the most convenient method to investigate the thermodynamic properties in binary and ternary solutions mainly found in food [6], cosmetics, material testing, underwater ranging, cleaning, leather, and [7,8] pharmaceutical industries. Ultrasonic and thermodynamics studies were done to analyze the mixture's nature and power of intermolecular interactions [9].

In our study, we include biotin at (0.000, 0.001, 0.002, 0.003) mol·kg^{-1} concentration and aqueous Propylene/ Hexylene glycol at a variant temperature from (288.15, 298.15, 308.15, 318.15) K. From the experimentally obtained values density and speed of sound evaluated various physicochemical properties like Adiabatic compressibility, Intermolecular free length, Rao's constant, Acoustic impedance, Vander Waal's constant, Wada's constant.

Glycols are colorless and excellent solvents for water-insoluble [10] chemicals and drugs. They are members of the alcohol family [11]. Propylene glycol is a synthetic and syrupy liquid which have no taste. They absorb extra water and maintain moisture in food products and cosmetics [12]. PG is mainly used to make polyester compounds [13] and is used as an antifreeze in chemical, food, and pharmaceutical industries. It is also used as a preservative [14] to make fog and smoke. Used in paints and plastic industries as solvent. Hexylene glycols are miscible with water and biodegradable. It is derived from acetone, having two functions of alcohol. It is a coupling agent [15]. Used as a solvent in cosmetics, construction, coatings, textiles, leather, fragrances, printing inks, and fuels.

Good health is central to human happiness and well-being. For a healthy life cycle, we need a healthy and balanced diet. Vitamins are essential nutrients as they perform many roles in our body. Biotin, also known as vitamin B_7 or vitamin H. It is a water-soluble vitamin that helps convert food into energy. We need to intake biotin as necessary as it is not stored in our bodies. It is mainly found in many food items like milk, egg, bananas, mushrooms, cheese, cauliflower, sweet potatoes, and nuts. It helps us in many ways, as our body metabolizes fats, carbohydrates [16], and protein. It can strengthen brittle nails. It improves the skin, creates a glow, and promotes healthy hair-like volume and shine. It is highly beneficial for breastfeeding and pregnant women. Biotin also helps in rapid weight loss. It has the ability to lower blood sugar levels [17]. In animals prevent insulin resistance.

2. Materials and Methods

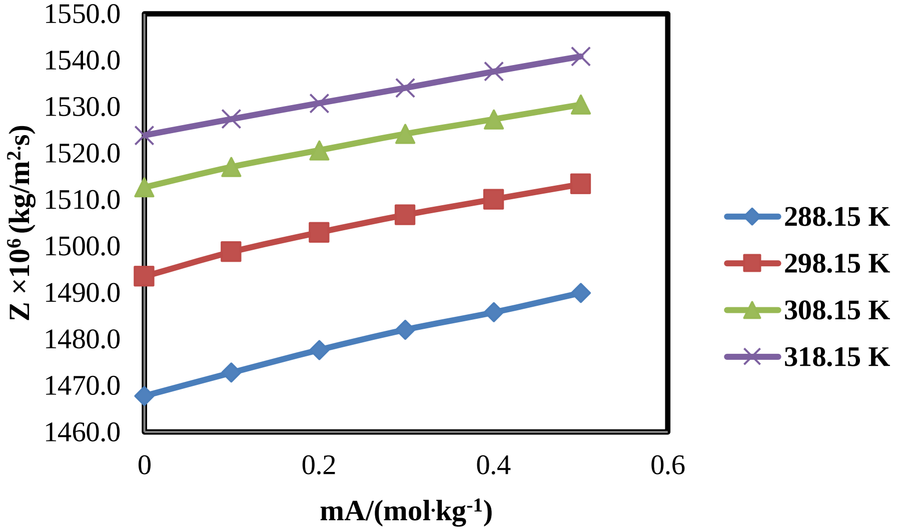
In this work, we used chemicals from Loba Chemie Pvt. Ltd. having mass fraction purity greater than 0.99. Biotin (Vitamin B_7) with molar mass 244.31($g \cdot mol^{-1}$), Propylene Glycols with 76.09($g \cdot mol^{-1}$) and Hexylene Glycol with 118.176($g \cdot mol^{-1}$). After vacuum drying, the sample is kept in desiccators over P_2O_5 for two days for purification. Triple distilled and degassed water is used for the preparation of the solution.

The ternary mixture contained biotin, water, and Propylene glycol (PG)/ Hexylene glycol (HG) at a variant temperature range from (288.15 to 318.15) K over-concentration (0.000 to 0.003)$mol \cdot kg^{-1}$determined the density and speed of sound using the instrument Anton Paar DSA 5000 M at constant pressure 0.1 MPa and frequency 3 MHz. The aqueous solution is inserted with the help of a syringe. Inside the apparatus, there are two cells that are filled automatically and measure the density and speed of sound simultaneously with accuracy at the same time. The Peltier thermostat controls the temperature built in the DSA 5000 M. Triple distilled and degassed water has specific conductance $< 10^{-6} s \cdot cm^{-1}$.Uncertainties of temperature, speed of sound, and density are ±0.001 K, ±1.0 $m \cdot s^{-1}$, and ±0.15$kg \cdot m^{-3}$.

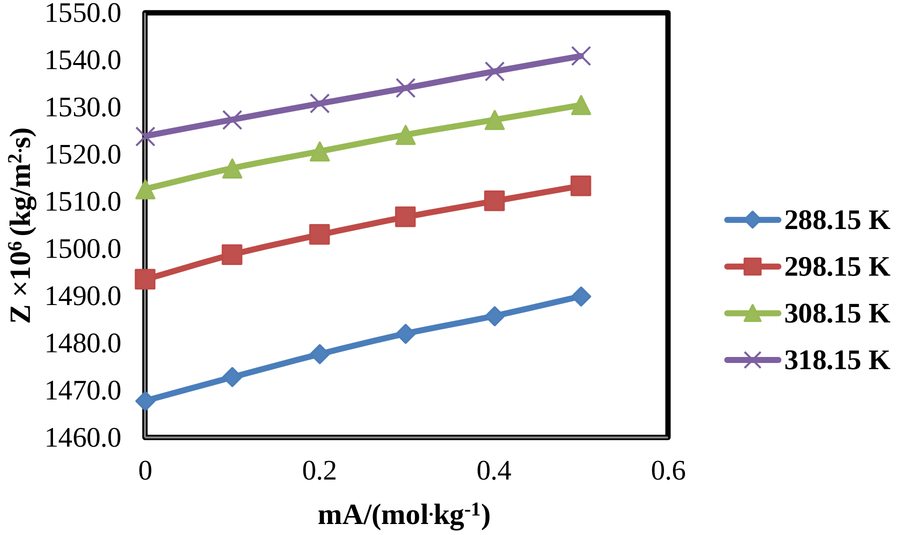
Table 1. At variant temperatures, values of Acoustic impedance (Z), adiabatic compressibility (β), of glycols in biotin solution.

$^{a}m_A$/(mol·kg^{-1})	Z×10^{6}(kg/m^{2}·s)				β×10^{-10}(m^{2}/N)			
	T=288.15 K	*T*=298.15 K	*T* =308.15 K	*T* =318.15 K	*T* =288.15 K	*T* =298.15 K	*T* =308.15 K	*T* =318.15 K
0.000 mol·kg^{-1} biotin + PG								
0.00000	1465.50	1491.437	1510.09	1521.21	4.65	4.48	4.36	4.28
0.10028	1470.34	1496.768	1514.45	1524.71	4.62	4.45	4.34	4.26
0.20000	1475.18	1500.969	1518.05	1528.12	4.59	4.43	4.32	4.24
0.30017	1479.62	1504.748	1521.64	1531.48	4.57	4.41	4.30	4.23
0.40905	1483.67	1508.259	1525.06	1535.21	4.54	4.39	4.28	4.21
0.50000	1487.28	1511.386	1527.89	1538.04	4.52	4.37	4.26	4.19
0.001 mol·kg^{-1} biotin + PG								
0.00000	1467.7	1493.5	1512.7	1523.9	4.64	4.47	4.35	4.27
0.09990	1472.8	1498.7	1517.1	1527.3	4.61	4.44	4.32	4.25
0.20045	1477.7	1503.0	1520.6	1530.8	4.58	4.42	4.30	4.23
0.29880	1482.0	1506.7	1524.1	1534.0	4.55	4.40	4.28	4.21
0.40084	1485.8	1510.1	1527.3	1537.6	4.53	4.38	4.27	4.20
0.50009	1489.9	1513.3	1530.4	1540.8	4.51	4.36	4.25	4.18
0.002 mol·kg^{-1} biotin + PG								
0.00000	1470.17	1496.06	1514.98	1526.55	4.63	4.46	4.33	4.25
0.10071	1475.43	1501.38	1519.38	1530.01	4.59	4.43	4.31	4.24
0.19991	1480.18	1505.58	1522.94	1533.24	4.57	4.40	4.29	4.22
0.30027	1484.42	1509.23	1526.67	1536.65	4.54	4.38	4.27	4.20
0.40010	1488.16	1512.59	1529.64	1540.19	4.52	4.36	4.26	4.18
0.49000	1492.10	1515.47	1532.62	1543.12	4.50	4.35	4.24	4.17
0.003 mol·kg^{-1} biotin + PG								
0.00000	1473.48	1498.442	1517.96	1530.15	4.61	4.44	4.32	4.23
0.10087	1478.61	1503.738	1522.33	1533.37	4.57	4.41	4.29	4.22
0.20004	1483.24	1507.853	1525.76	1536.63	4.55	4.39	4.28	4.20
0.29996	1487.21	1511.676	1529.46	1539.99	4.52	4.37	4.26	4.18
0.40230	1491.27	1515.051	1532.61	1543.57	4.50	4.35	4.24	4.17
0.50006	1495.78	1518.331	1535.87	1546.68	4.47	4.33	4.22	4.15
0.000 mol·kg^{-1} biotin + HG								
0.00000	1465.50	1491.44	1510.09	1521.21	4.65	4.48	4.36	4.28
0.09976	1475.59	1499.95	1517.33	1527.58	4.59	4.43	4.32	4.25
0.20012	1485.43	1509.32	1524.25	1534.93	4.53	4.38	4.28	4.21
0.30214	1494.77	1518.15	1532.03	1541.67	4.47	4.33	4.24	4.17
0.39996	1503.72	1525.70	1537.66	1547.00	4.42	4.29	4.21	4.14
0.50067	1510.83	1533.03	1542.67	1552.25	4.38	4.25	4.18	4.12
0.001 mol·kg^{-1} biotin + HG								
0.00000	1467.75	1493.47	1512.65	1523.85	4.64	4.47	4.35	4.27
0.10100	1477.95	1502.40	1520.17	1530.64	4.58	4.42	4.30	4.23
0.20035	1488.17	1511.44	1527.25	1538.07	4.51	4.37	4.27	4.19

$^{a}m_A$/(mol·kg^{-1})	Z×10^6(kg/m^2·s)				β×10^{-10}(m^2/N)			
	T=288.15 K	*T*=298.15 K	*T* =308.15 K	*T* =318.15 K	*T* =288.15 K	*T* =298.15 K	*T* =308.15 K	*T* =318.15 K
0.29989	1497.00	1520.19	1534.97	1544.51	4.46	4.32	4.22	4.16
0.40002	1506.64	1527.73	1540.57	1549.97	4.41	4.28	4.19	4.13
0.50210	1513.89	1535.15	1545.57	1555.22	4.36	4.24	4.17	4.10
0.002 mol·kg^{-1} biotin + HG								
0.00000	1470.17	1496.06	1514.98	1526.55	4.63	4.46	4.33	4.25
0.10002	1480.59	1504.91	1522.48	1533.21	4.56	4.41	4.29	4.22
0.20378	1491.24	1514.22	1530.09	1540.95	4.50	4.35	4.25	4.18
0.30087	1499.82	1522.71	1537.47	1547.24	4.45	4.31	4.21	4.14
0.39890	1509.54	1530.04	1542.94	1552.36	4.39	4.26	4.18	4.12
0.50010	1516.63	1537.38	1547.76	1557.72	4.35	4.22	4.16	4.09
0.003 mol·kg^{-1} biotin + HG								
0.00000	1473.48	1498.44	1517.96	1530.154	4.61	4.44	4.32	4.23
0.10072	1484.03	1507.44	1525.78	1537.19	4.54	4.39	4.27	4.20
0.20054	1494.23	1516.59	1533.07	1544.879	4.48	4.34	4.24	4.16
0.30341	1503.58	1525.40	1540.81	1551.364	4.43	4.29	4.19	4.12
0.40009	1512.97	1532.64	1545.58	1556.67	4.37	4.25	4.17	4.10
0.49981	1520.09	1540.02	1550.41	1561.586	4.33	4.21	4.14	4.07



(a)



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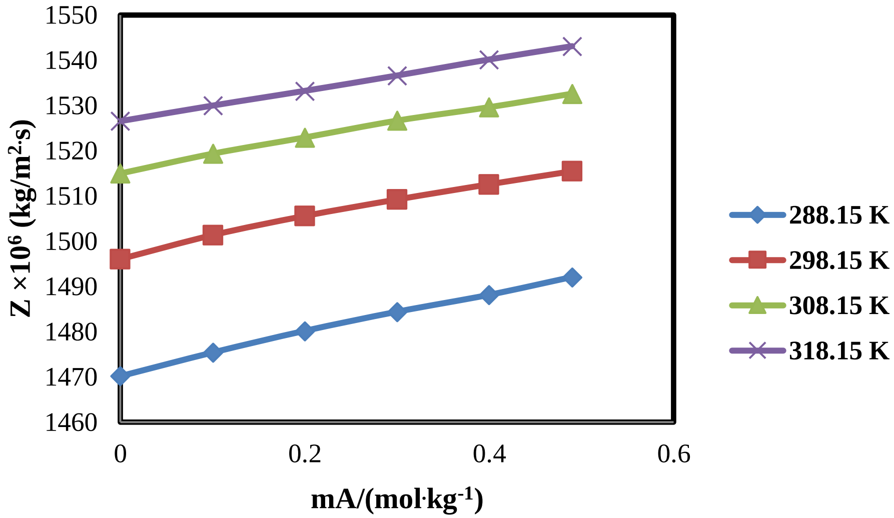
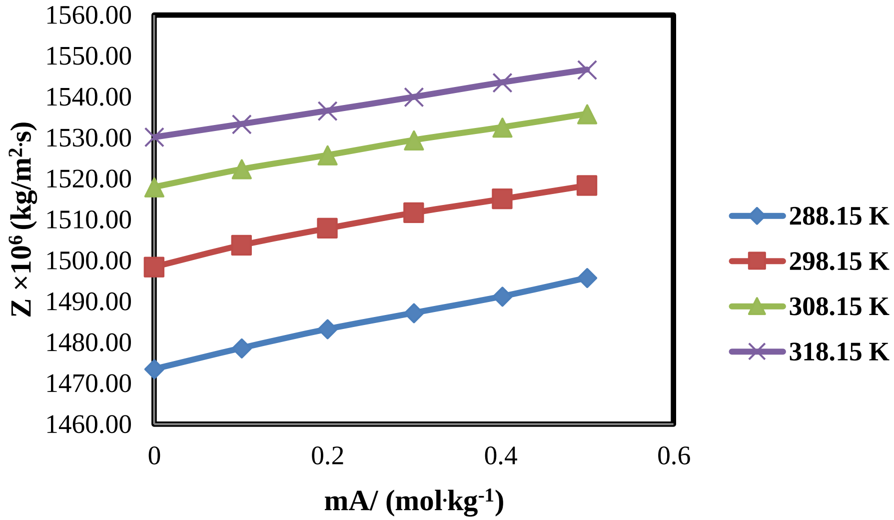

1550
1540
1530
1520
1510
1500
1490
1480
1470
1460
0
0.2
0.4
0.6
Z ×10⁶ (kg/m²·s)
mA/(mol·kg⁻¹)
288.15 K
298.15 K
308.15 K
318.15 K

(c)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1500.00
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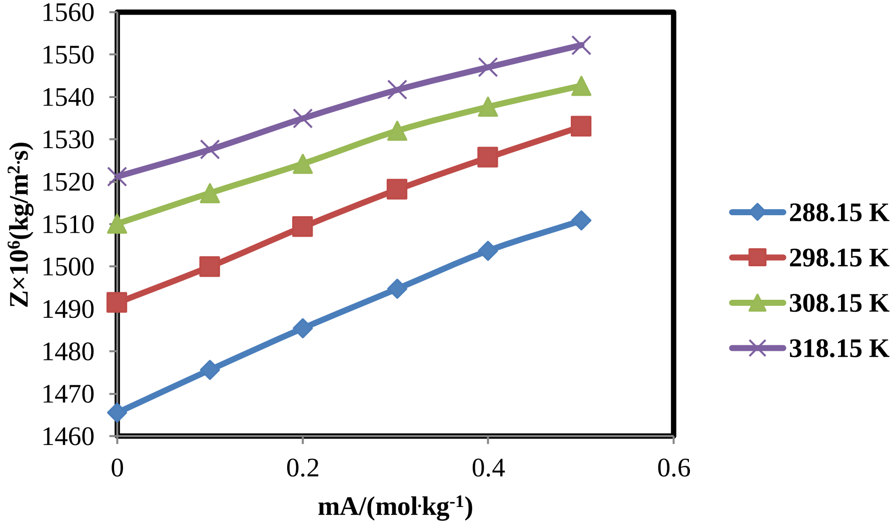
1460.00
0
0.2
0.4
0.6
Z ×10⁶ (kg/m²·s)
mA/ (mol·kg⁻¹)
288.15 K
298.15 K
308.15 K
318.15 K

(d)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1490
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1470
1460
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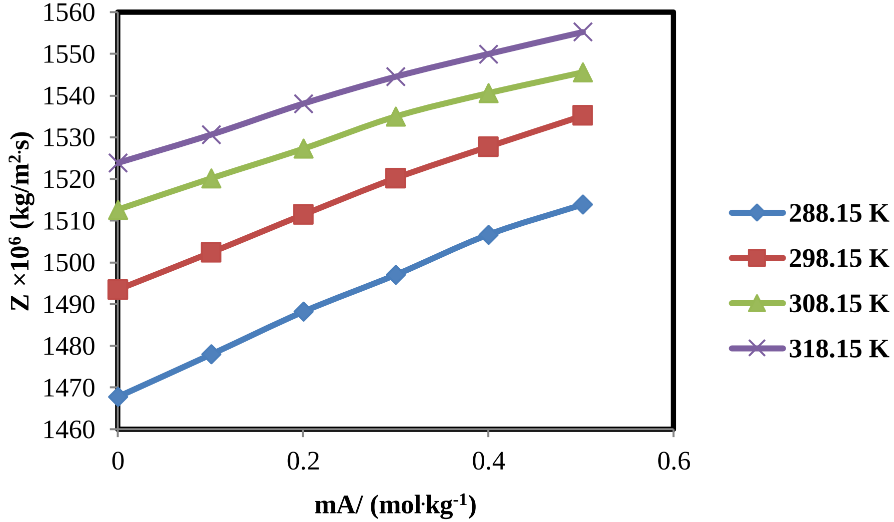
0.2
0.4
0.6
Z×10⁶(kg/m²·s)
mA/(mol·kg⁻¹)
288.15 K
298.15 K
308.15 K
318.15 K

(e)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1490
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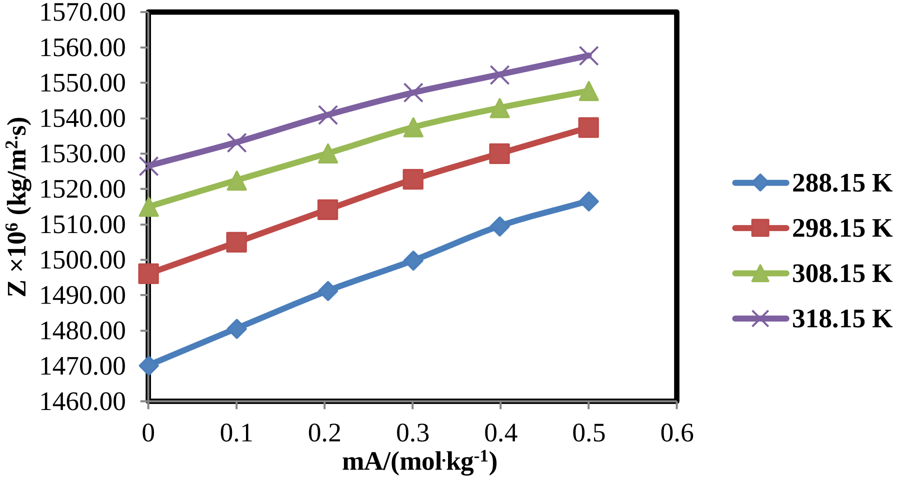
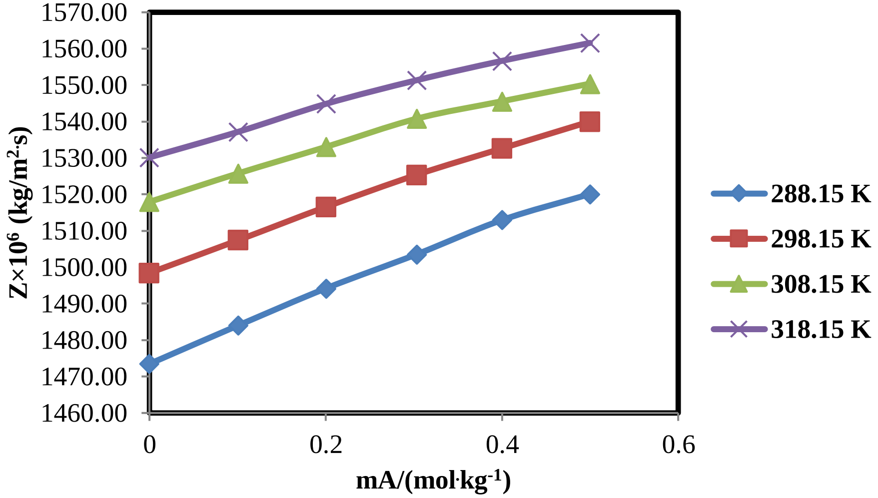
1470
1460
0
0.2
0.4
0.6
Z ×10⁶ (kg/m²·s)
mA/ (mol·kg⁻¹)
288.15 K
298.15 K
308.15 K
318.15 K

(f)

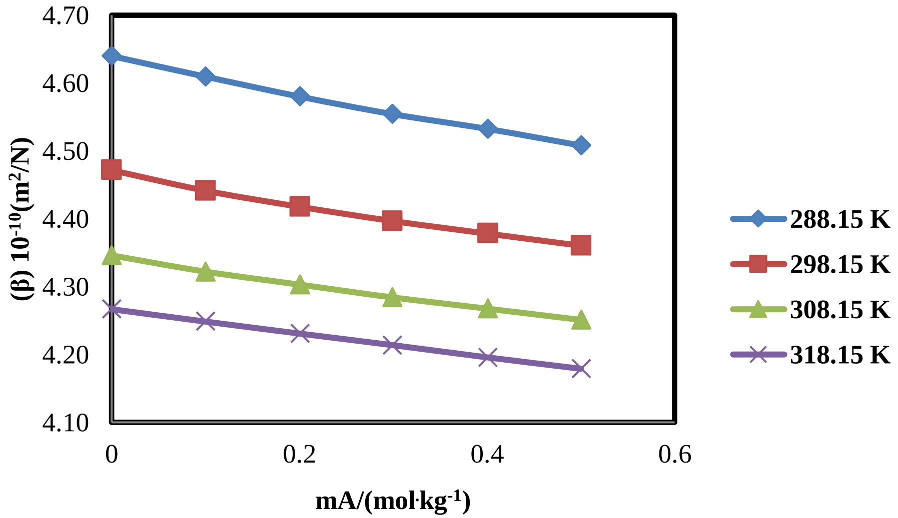


(g)

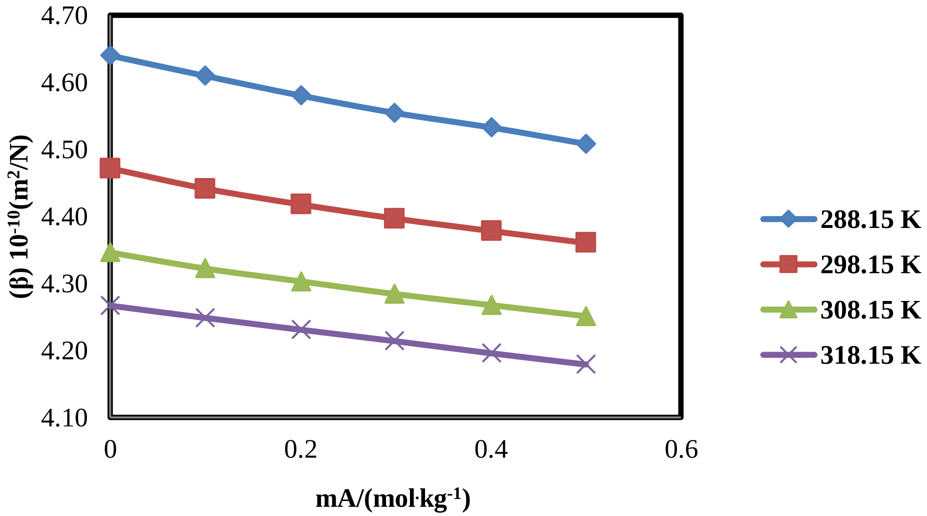


(h)

Figure 1. Variation of Acoustic Impedance(Z), correspondent to Molality (mA) of glycols in aqueous solution of biotin. (**a**) 0.000 biotin +PG; (**b**) 0.001 biotin +PG; (**c**) 0.002 biotin +PG; (**d**) 0.003 biotin +PG; (**e**) 0.000 biotin +HG; (**f**) 0.001 biotin +HG; (**g**) 0.002 biotin + HG and (**h**) 0.003 biotin + HG opposing molality of Different Temperatures.



(a)



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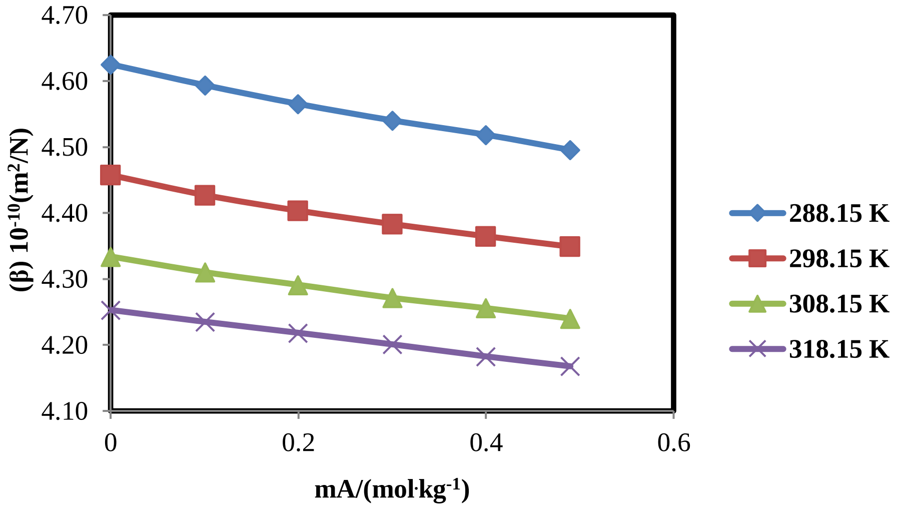
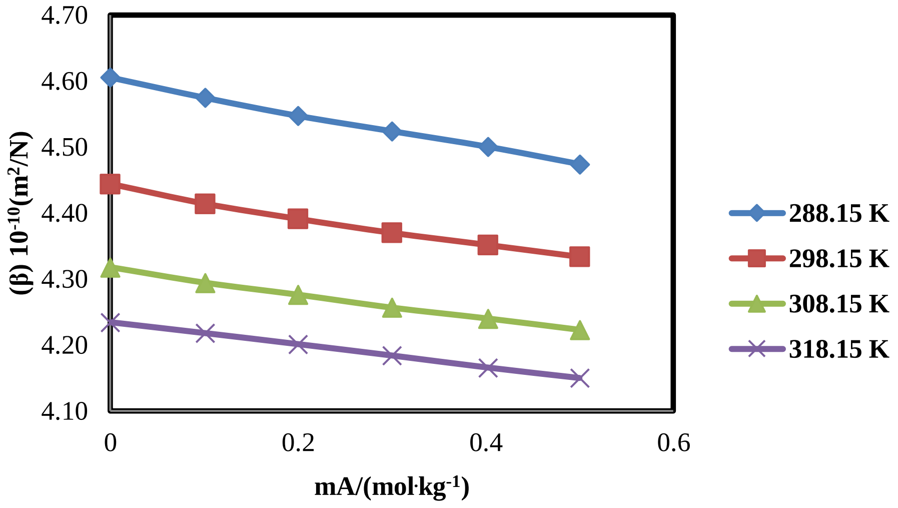
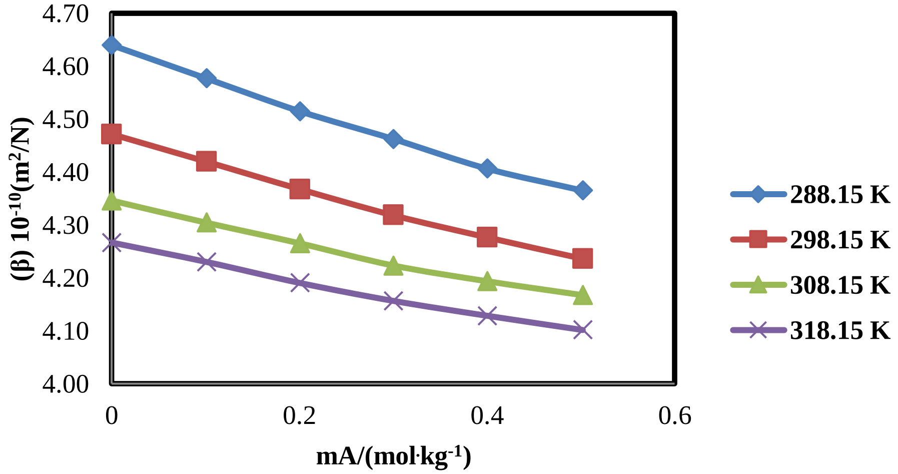

4.70
4.60
4.50
4.40
4.30
4.20
4.10
0
0.2
0.4
0.6
(β) 10^-10(m^2/N)
mA/(mol·kg^-1)
288.15 K
298.15 K
308.15 K
318.15 K

(c)


4.70
4.60
4.50
4.40
4.30
4.20
4.10
0
0.2
0.4
0.6
(β) 10^-10(m^2/N)
mA/(mol·kg^-1)
288.15 K
298.15 K
308.15 K
318.15 K

(d)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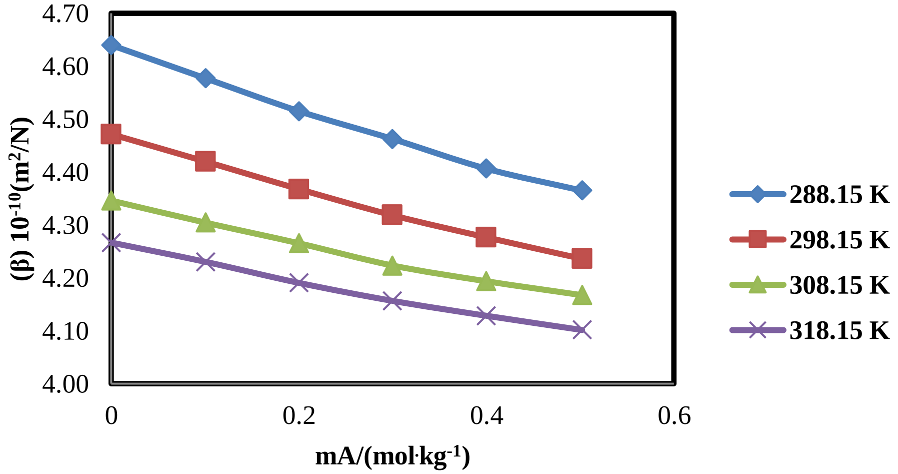
4.00
0
0.2
0.4
0.6
(β) 10^-10(m^2/N)
mA/(mol·kg^-1)
288.15 K
298.15 K
308.15 K
318.15 K

(e)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0.6
(β) 10^-10(m^2/N)
mA/(mol·kg^-1)
288.15 K
298.15 K
308.15 K
318.15 K

(f)

https://doi.org/10.33263/LIANBS124.133

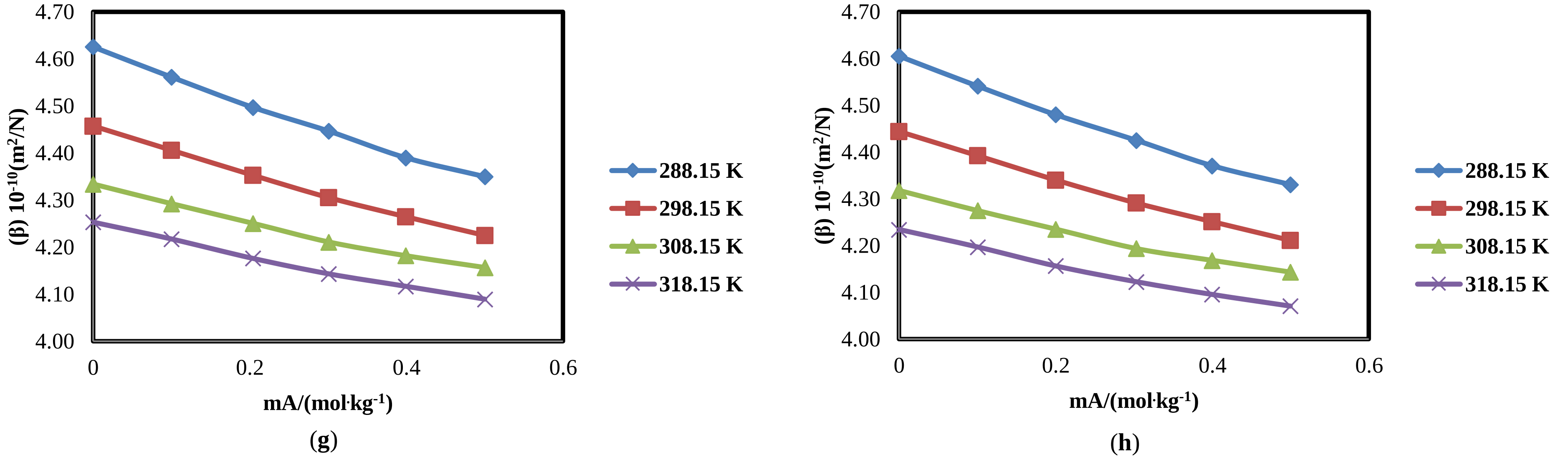


Figure 2. Variation of Adiabatic Compressibility (β), correspondent to the Molality (mA) of Glycols in aqueous solution of biotin.(**a**) 0.000 biotin +PG; (**b**) 0.001 biotin +PG; (**c**) 0.002 biotin +PG; (**d**) 0.003 biotin +PG; (**e**) 0.000 biotin +HG; (**f**) 0.001 biotin +HG; (**g**) 0.002 biotin + HG and (**h**) 0.003 biotin + HG opposing molality of Different Temperatures.

3. Results and Discussion

Density and ultrasonic velocity increase with the increase in concentration in the aqueous solution of Biotin with PG/ HG at a variant temperature from (288.15 to 318.15) K and different concentrations (0.000 to 0.003) $mol \cdot kg^{-1}$ at a constant frequency range of 3 MHz. But the density values vary with an increase in temperature as it falls, and velocity rises as temperature rises [18,19]. Using the experimental obtained data of density and ultrasonic velocity, thermo-acoustic parameters such as Acoustic impedance (Z), Adiabatic compressibility (β), Wada's constant (W), Rao's constant (R), Intermolecular free length (L_f) and Vander Waal's constant (b) were determined using the formula given below:

3.1. Acoustic impedance (Z).

$$Z = \rho \times U \quad (1)$$

ρ is the density of the medium, and U is the ultrasonic velocity of the sample.

It is observed that acoustic impedance increases [20] with an increase in concentration. The values are represented in Table 1. This implies a molecular interaction [21] between the aqueous mixture. This is graphically represented in Figure 1.

3.2. Adiabatic compressibility (β).

$$\beta = \frac{1}{(c^2 \times \rho)} \quad (2)$$

c is the ultrasonic velocity or speed of sound of the aqueous solution.

The solvent molecule is around the solute molecule, so adiabatic compressibility decreases [22] with an increase in concentration represented in Table 1. This indicates strong molecular interaction between the liquid mixture [23-24] and is shown in Figure 2.

3.3. Wada's constant (W)

$$W = (\beta)^{-1/7} M_{eff} / \rho \quad (3)$$

β is adiabatic compressibility and M_{eff} is effective molecular weight of the solution.

As density and ultrasonic velocity increases with concentration. The gap between the molecules decreases [25] can be seen in Figure 3. as concentration increases and Wada's constant also increases, as represented in Table 2.

3.4. Rao's constant (R).

$$R = c^{1/3} M_{eff} / \rho \quad (4)$$

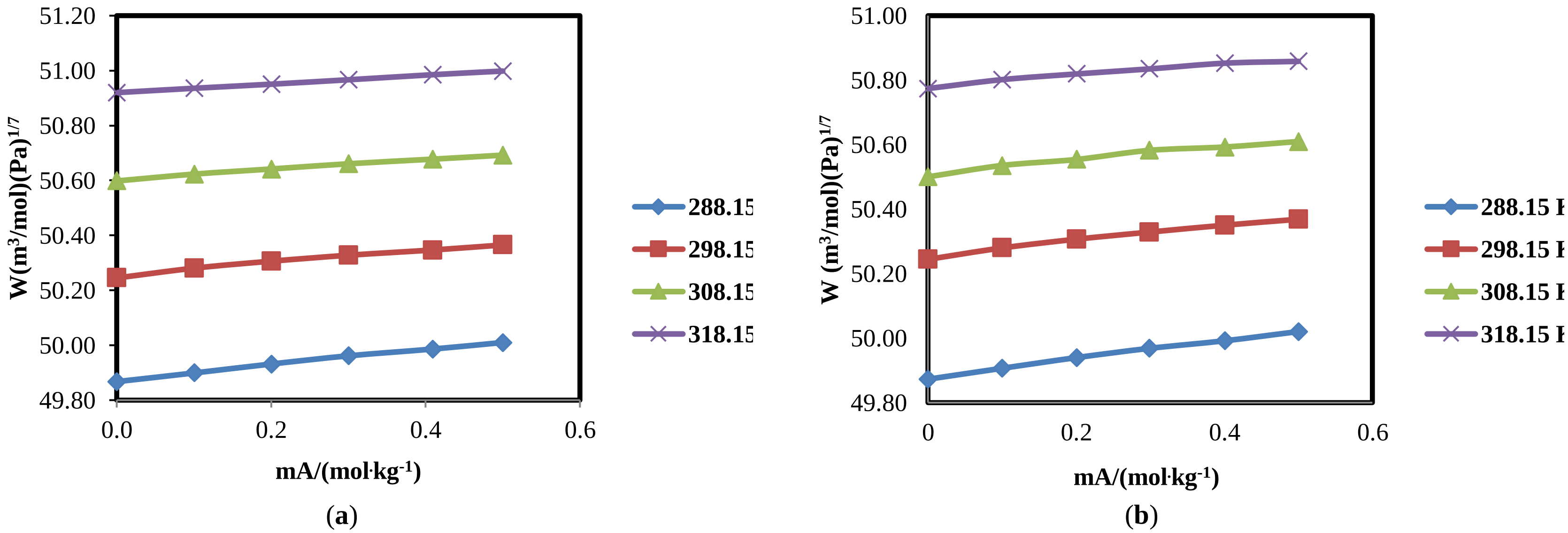
R is temperature independent.

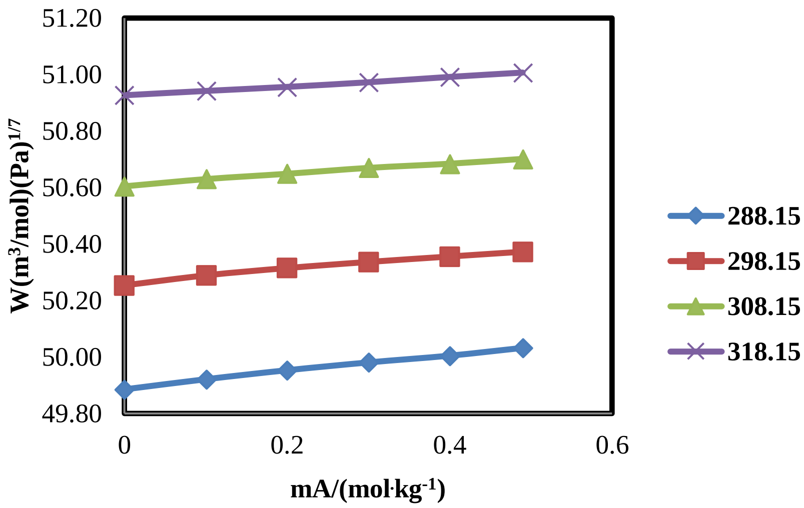
It is represented in Table 2. and shown in Figure 4. that Rao's constant is increasing with an increase in concentration, and the molecules are closely packed [26-27].

Table 2. At variant temperatures, values of Wada's constant (W), Rao's constant (R), of glycols in biotin solution.

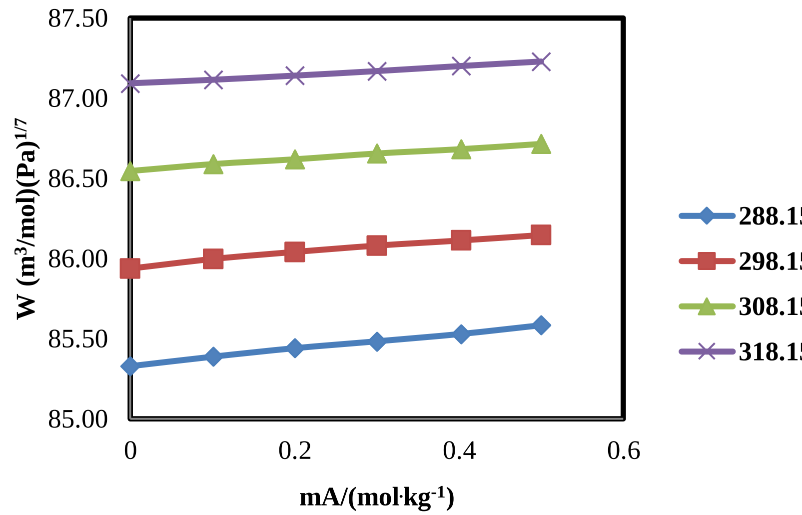
$^{a}m_A$/(mol·kg^{-1})	W(m^3/mol)(Pa)$^{1/7}$				R(m^3/mol)(m/s)$^{1/3}$			
	***T*=288.15 K**	***T*=298.15 K**	***T* =308.15 K**	***T* =318.15 K**	***T* =288.15 K**	***T* =298.15 K**	***T* =308.15 K**	***T* =318.15 K**
0.000 mol·kg^{-1} biotin + PG								
0.00000	49.87	50.24	50.60	50.92	705.73	711.97	717.81	723.14
0.10028	49.90	50.28	50.62	50.94	706.25	712.56	718.22	723.40
0.20000	49.93	50.31	50.64	50.95	706.79	712.98	718.53	723.65
0.30017	49.96	50.33	50.66	50.97	707.28	713.34	718.85	723.91
0.40905	49.99	50.35	50.68	50.98	707.69	713.65	719.12	724.22
0.50000	50.01	50.37	50.69	51.00	708.08	713.95	719.37	724.44
0.001 mol·kg^{-1} biotin + PG								
0.00000	49.87	50.24	50.50	50.77	705.82	711.99	717.85	723.14
0.09990	49.91	50.28	50.54	50.80	706.38	712.57	718.27	723.40
0.20045	49.94	50.31	50.55	50.82	706.92	712.99	718.57	723.65
0.29880	49.97	50.33	50.58	50.83	707.40	713.35	718.88	723.91
0.40084	49.99	50.35	50.59	50.85	707.79	713.67	719.15	724.21
0.50009	50.02	50.37	50.61	50.86	708.26	713.98	719.43	724.49
0.002 mol·kg^{-1} biotin + PG								
0.00000	49.89	50.25	50.60	50.93	706.03	712.11	717.91	723.25
0.10071	49.92	50.29	50.63	50.94	706.62	712.70	718.34	723.51
0.19991	49.95	50.31	50.65	50.96	707.15	713.12	718.65	723.74
0.30027	49.98	50.34	50.67	50.97	707.60	713.48	718.99	724.01
0.40010	50.00	50.36	50.68	50.99	708.00	713.80	719.24	724.33
0.49000	50.03	50.37	50.70	51.01	708.45	714.08	719.52	724.58
0.003 mol·kg^{-1} biotin + PG								
0.00000	85.33	85.94	86.55	87.09	1207.75	1217.81	1227.88	1236.94
0.10087	85.39	86.00	86.59	87.12	1208.73	1218.80	1228.59	1237.31
0.20004	85.44	86.04	86.62	87.14	1209.60	1219.52	1229.09	1237.73
0.29996	85.48	86.08	86.66	87.17	1210.31	1220.18	1229.68	1238.20
0.40230	85.53	86.11	86.68	87.20	1211.07	1220.71	1230.13	1238.73
0.50006	85.58	86.15	86.71	87.23	1211.97	1221.26	1230.67	1239.19
0.000 mol·kg^{-1} biotin + HG								
0.00000	85.26	85.90	86.51	87.06	1206.58	1217.24	1227.23	1236.34
0.09976	85.41	86.02	86.60	87.13	1209.05	1219.23	1228.79	1237.61
0.20012	85.55	86.16	86.69	87.23	1211.44	1221.43	1230.30	1239.14
0.30214	85.69	86.28	86.80	87.31	1213.70	1223.48	1232.01	1240.53
0.39996	85.82	86.39	86.87	87.37	1215.86	1225.23	1233.18	1241.56
0.50067	85.92	86.49	86.93	87.43	1217.53	1226.89	1234.19	1242.56
0.001 mol·kg^{-1} biotin + HG								
0.00000	85.27	85.90	86.51	87.06	1206.73	1217.27	1227.30	1236.34
0.10100	85.42	86.03	86.61	87.14	1209.22	1219.35	1228.93	1237.72
0.20035	85.57	86.16	86.70	87.24	1211.73	1221.48	1230.49	1239.30
0.29989	85.70	86.28	86.81	87.31	1213.86	1223.54	1232.22	1240.61
0.40002	85.84	86.39	86.88	87.38	1216.20	1225.28	1233.36	1241.67
0.50210	85.94	86.49	86.94	87.44	1217.91	1226.98	1234.38	1242.70

$^{a}m_A$/(mol·kg^{-1})	W(m^3/mol)(Pa)$^{1/7}$				R(m^3/mol)(m/s)$^{1/3}$			
	T=288.15 K	*T*=298.15 K	*T* =308.15 K	*T* =318.15 K	*T* =288.15 K	*T* =298.15 K	*T* =308.15 K	*T* =318.15 K
0.002 mol·kg^{-1} biotin + HG								
0.00000	120.70	121.59	122.44	123.22	1708.25	1722.97	1737.01	1749.93
0.10002	120.92	121.77	122.58	123.33	1711.87	1725.93	1739.36	1751.83
0.20378	121.14	121.96	122.72	123.47	1715.57	1729.02	1741.71	1754.16
0.30087	121.32	122.13	122.86	123.59	1718.49	1731.85	1744.04	1756.00
0.39890	121.52	122.27	122.96	123.67	1721.87	1734.26	1745.66	1757.39
0.50010	121.67	122.42	123.04	123.76	1724.22	1736.63	1747.03	1758.90
0.003 mol·kg^{-1} biotin + HG								
0.00000	120.76	121.62	122.48	123.25	1709.19	1723.43	1737.68	1750.50
0.10072	120.98	121.80	122.63	123.38	1712.85	1726.41	1740.15	1752.57
0.20054	121.19	121.98	122.77	123.52	1716.40	1729.48	1742.42	1754.90
0.30341	121.39	122.16	122.91	123.63	1719.60	1732.41	1744.86	1756.78
0.40009	121.58	122.30	122.99	123.72	1722.86	1734.77	1746.21	1758.26
0.49981	121.73	122.45	123.08	123.80	1725.23	1737.20	1747.61	1759.61

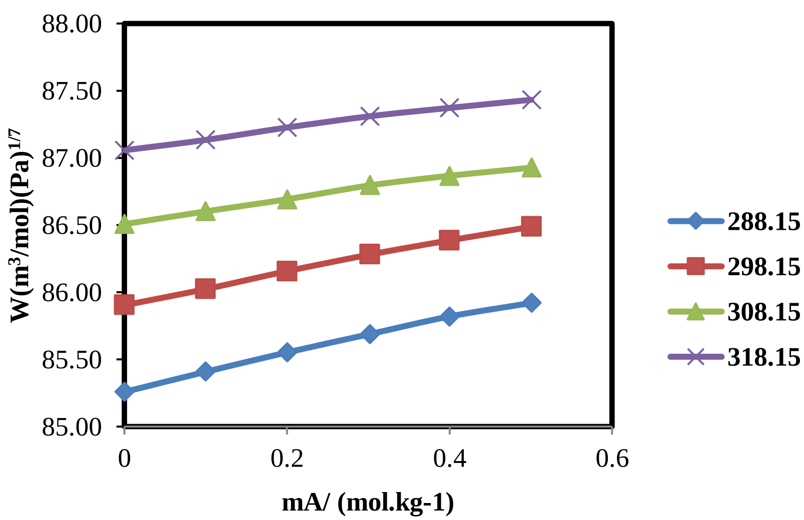



51.20
51.00
50.80
50.60
50.40
50.20
50.00
49.80
W(m3/mol)(Pa)1/7
0
0.2
0.4
0.6
mA/(mol·kg-1)
288.15
298.15
308.15
318.15

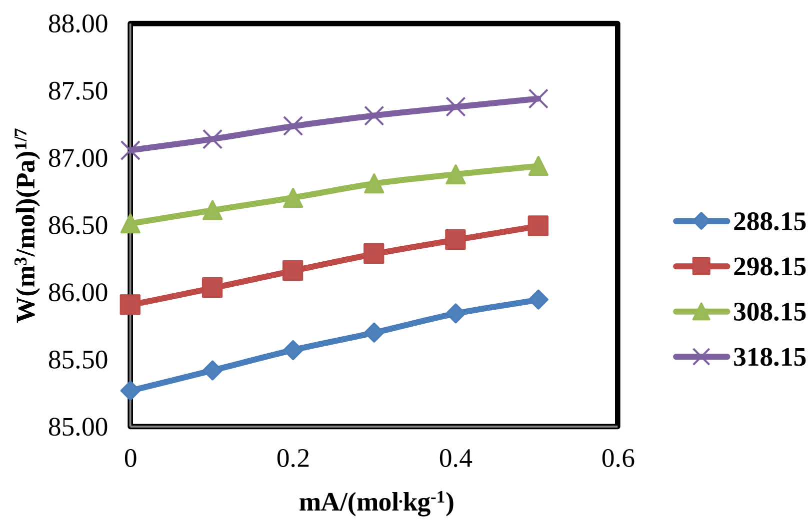
(c)


87.50
87.00
86.50
86.00
85.50
85.00
W (m3/mol)(Pa)1/7
0
0.2
0.4
0.6
mA/(mol·kg-1)

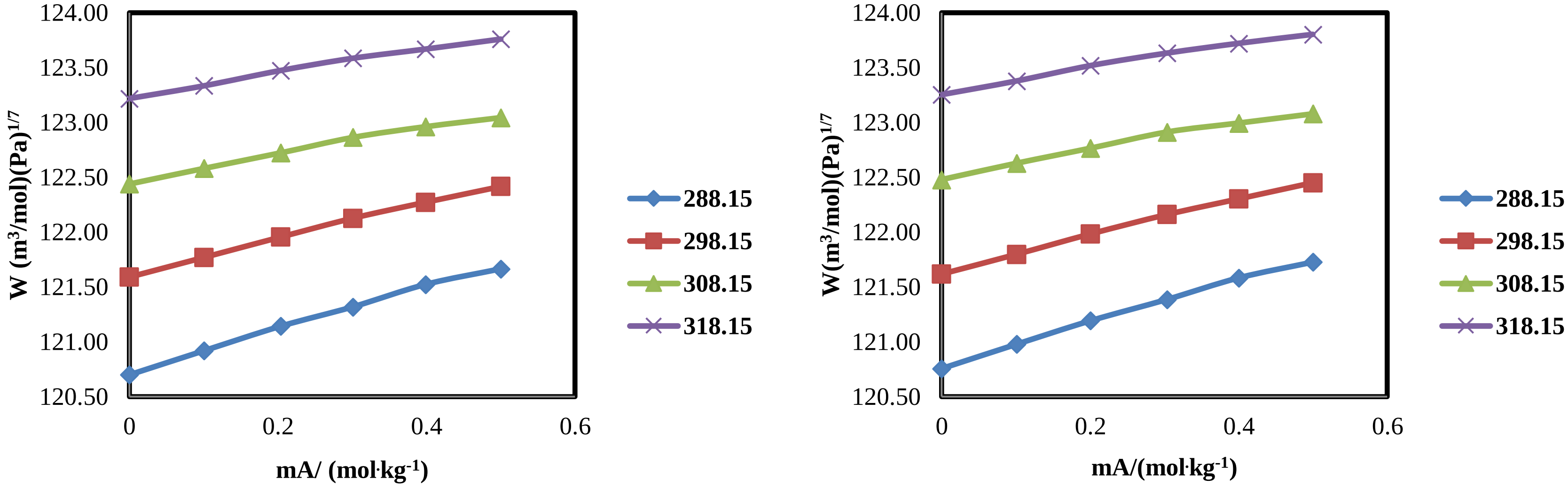
(d)


88.00
87.50
87.00
86.50
86.00
85.50
85.00
W(m3/mol)(Pa)1/7
0
0.2
0.4
0.6
mA/ (mol.kg-1)
288.15
298.15
308.15
318.15

(e)

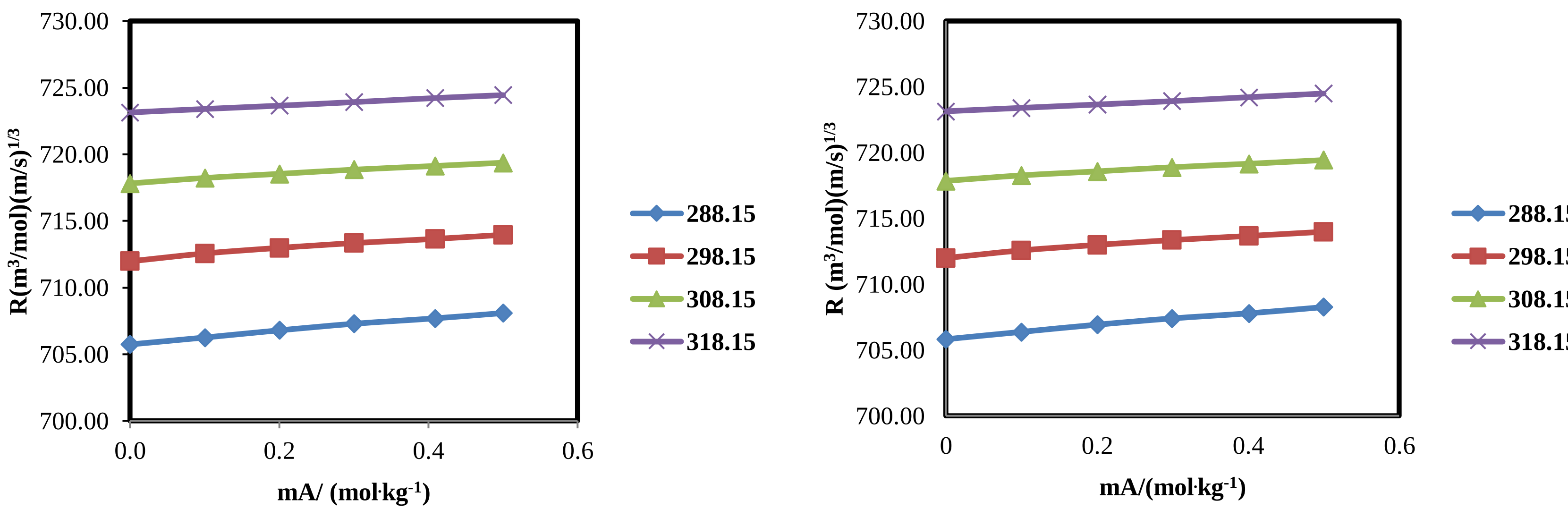

88.00
87.50
87.00
86.50
86.00
85.50
85.00
W(m3/mol)(Pa)1/7
0
0.2
0.4
0.6
mA/(mol·kg-1)
288.15
298.15
308.15
318.15

(f)

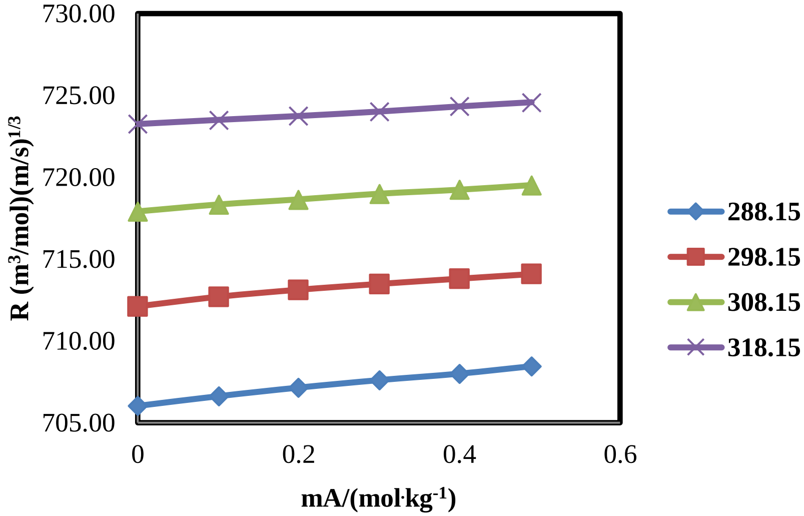


(g) (h)

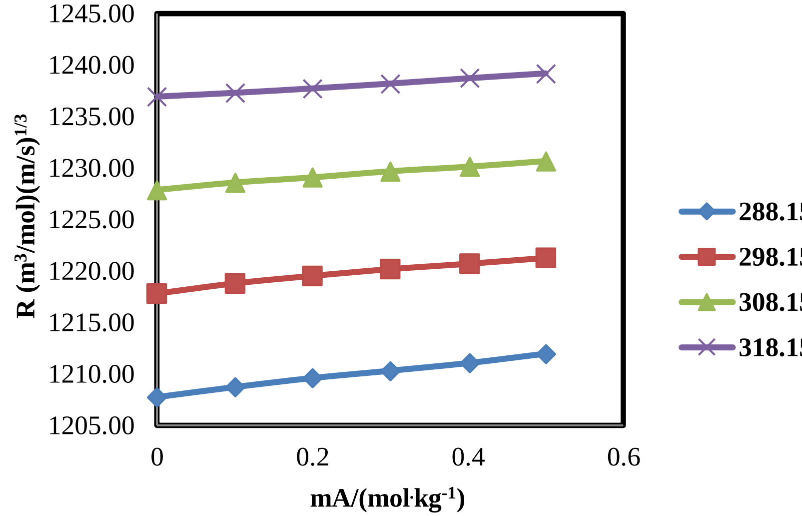
Figure 3. Variation of Wada's Constant, W, correspondent to the Molality (mA) of Glycols in aqueous solution of biotin. (**a**) 0.000 biotin +PG; (**b**) 0.001 biotin +PG; (**c**) 0.002 biotin +PG; (**d**) 0.003 biotin +PG; (**e**) 0.000 biotin +HG; (**f**) 0.001 biotin +HG; (**g**) 0.002 biotin + HG and (**h**) 0.003 biotin + HG opposing molality of Different Temperatures.



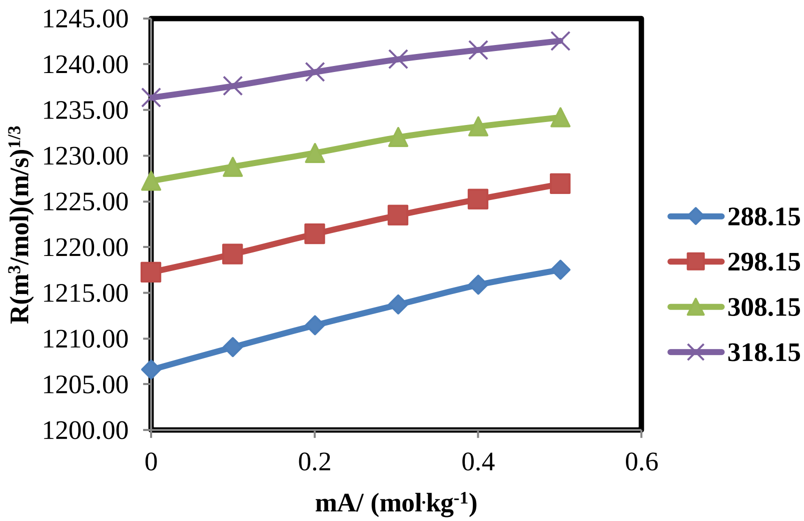
(a) (b)


R (m³/mol)(m/s)^1/3
mA/(mol·kg⁻¹)
288.15
298.15
308.15
318.15

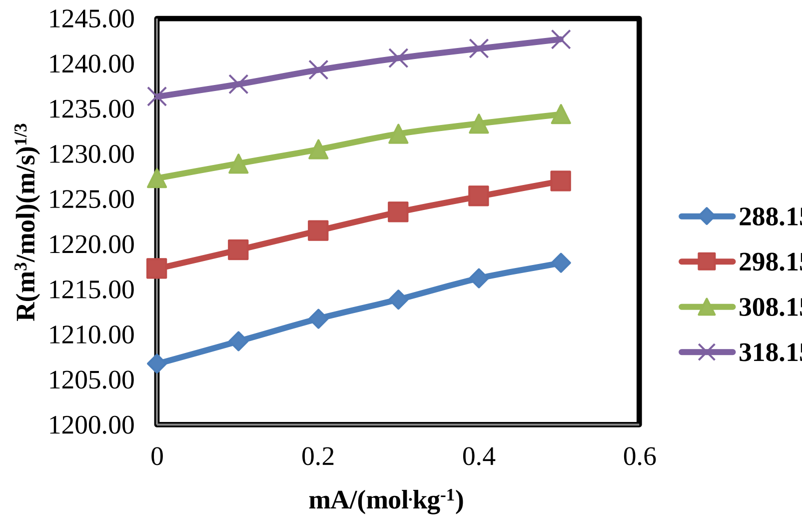
(c)


R (m³/mol)(m/s)^1/3
mA/(mol·kg⁻¹)
288.15
298.15
308.15
318.15

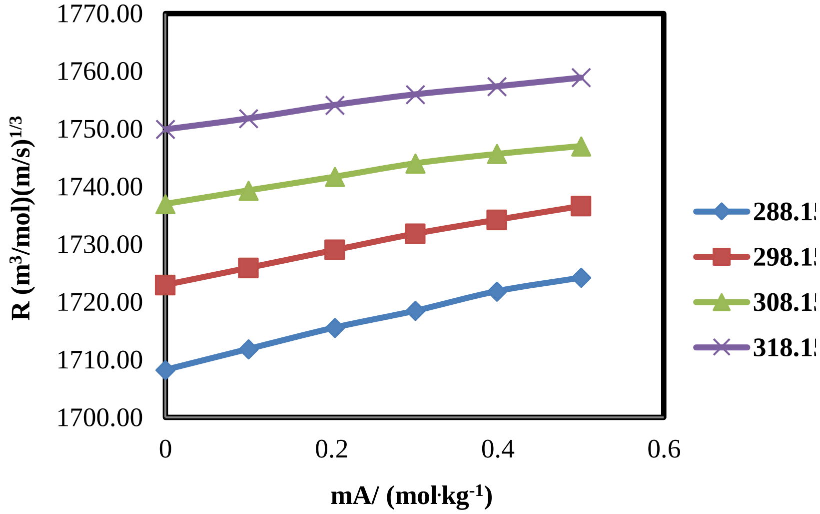
(d)


R(m³/mol)(m/s)^1/3
mA/ (mol·kg⁻¹)
288.15
298.15
308.15
318.15

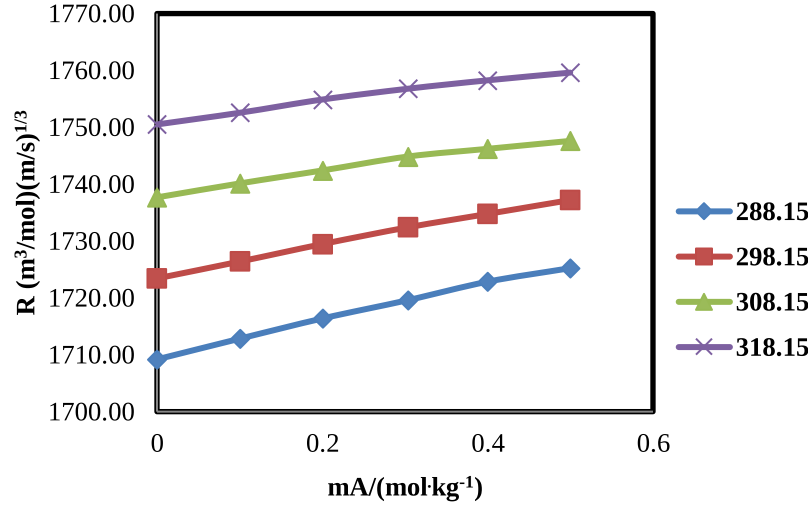
(e)


R(m³/mol)(m/s)^1/3
mA/(mol·kg⁻¹)
288.15
298.15
308.15
318.15

(f)



(g)



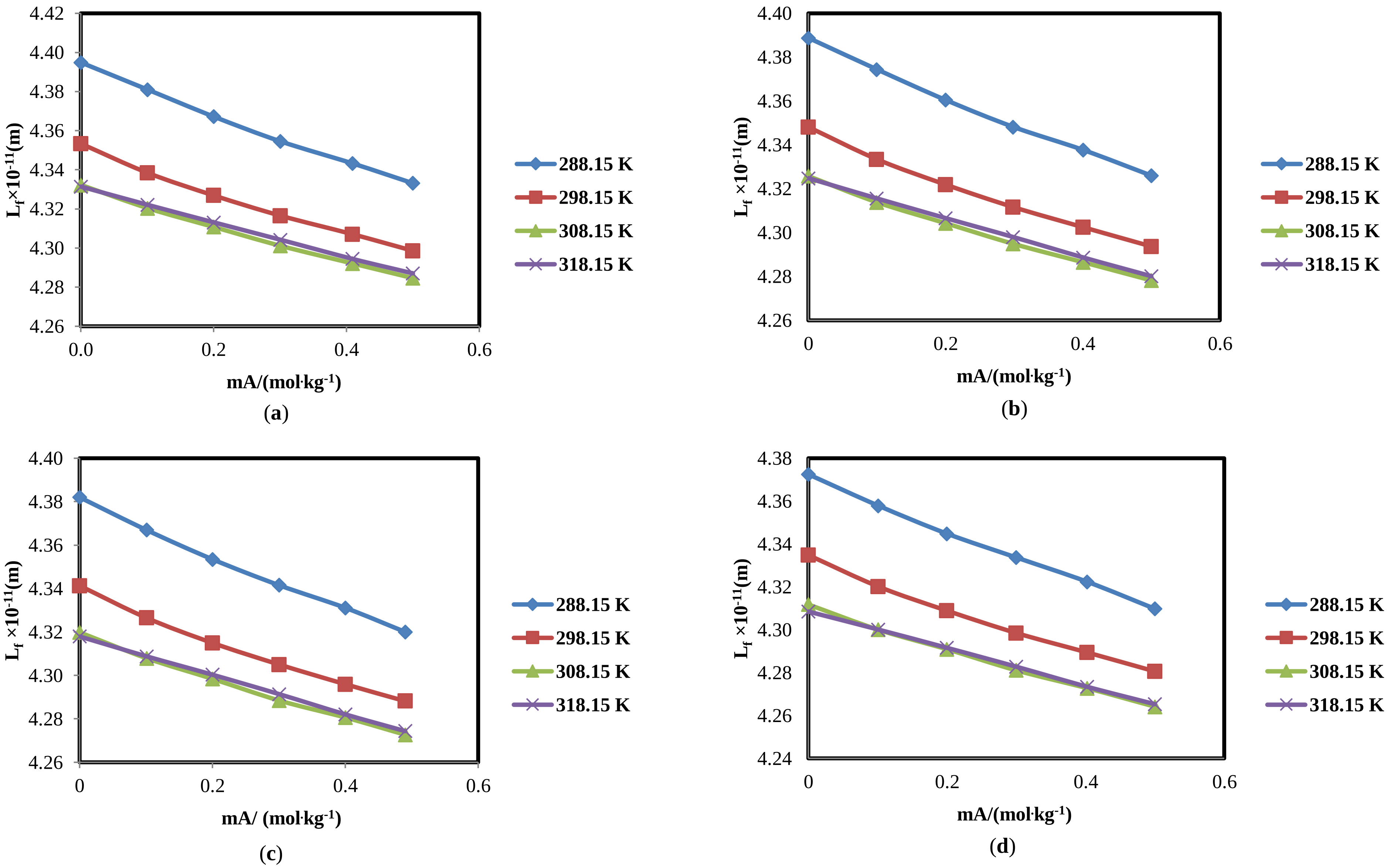
(h)

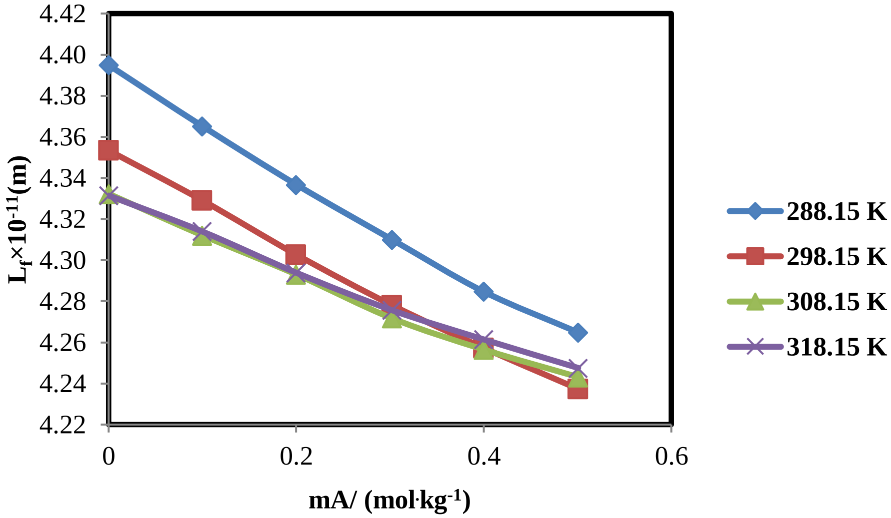
Figure 4. Variation of Rao's Constant, R, correspondent to the Molality(mA) of Glycols in an aqueous solution of biotin. (**a**) 0.000 biotin +PG; (**b**) 0.001 biotin +PG; (**c**) 0.002 biotin +PG; (**d**) 0.003 biotin +PG; (**e**) 0.000 biotin +HG; (**f**) 0.001 biotin +HG; (**g**) 0.002 biotin + HG and (**h**) 0.003 biotin + HG opposing molality of Different Temperatures.

Table 3. At variant temperatures, values of Intermolecular free length (L_f), Vander Waal's constant (b), of glycols in biotin solution.

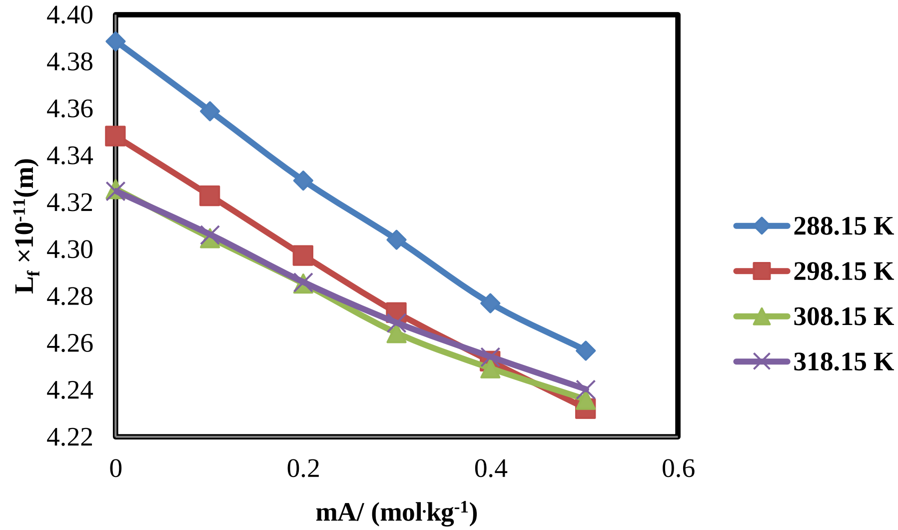
$^a m_A$/(mol·kg^{-1})	$L_f \times 10^{-11}$(m)				b(m^3/mol)			
	T=288.15 K	*T*=298.15 K	*T* =308.15 K	*T* =318.15 K	*T* =288.15 K	*T* =298.15 K	*T* =308.15 K	*T* =318.15 K
0.000 mol·kg^{-1} biotin + PG								
0.00000	4.39	4.35	4.33	4.33	122.82	123.10	123.48	123.93
0.10028	4.38	4.34	4.32	4.32	122.79	123.07	123.44	123.90
0.20000	4.37	4.33	4.31	4.31	122.76	123.04	123.41	123.86
0.30017	4.35	4.32	4.30	4.30	122.74	123.01	123.38	123.83
0.40905	4.34	4.31	4.29	4.29	122.71	122.98	123.35	123.80
0.50000	4.33	4.30	4.28	4.29	122.69	122.96	123.33	123.77
0.001 mol·kg^{-1} biotin + PG								
0.00000	4.39	4.35	4.33	4.32	122.78	123.06	123.43	123.88
0.09990	4.37	4.33	4.31	4.32	122.76	123.03	123.40	123.85
0.20045	4.36	4.32	4.30	4.31	122.73	123.00	123.37	123.81
0.29880	4.35	4.31	4.29	4.30	122.70	122.98	123.34	123.78
0.40084	4.34	4.30	4.29	4.29	122.68	122.95	123.31	123.75
0.50009	4.33	4.29	4.28	4.28	122.66	122.93	123.29	123.72
0.002 mol·kg^{-1} biotin + PG								
0.00000	4.38	4.34	4.32	4.32	122.76	123.03	123.39	123.84
0.10071	4.37	4.33	4.31	4.31	122.73	123.00	123.36	123.81

$^{a}m_A$/(mol·kg^{-1})	**L_f×10^{-11}(m)**				**b(m^3/mol)**			
	***T*=288.15 K**	***T*=298.15 K**	***T* =308.15 K**	***T* =318.15 K**	***T* =288.15 K**	***T* =298.15 K**	***T* =308.15 K**	***T* =318.15 K**
0.19991	4.35	4.31	4.30	4.30	122.71	122.97	123.33	123.78
0.30027	4.34	4.31	4.29	4.29	122.68	122.94	123.30	123.75
0.40010	4.33	4.30	4.28	4.28	122.66	122.92	123.28	123.72
0.49000	4.32	4.29	4.27	4.27	122.64	122.90	123.26	123.69
0.003 mol·kg^{-1} biotin + PG								
0.00000	4.37	4.33	4.31	4.31	209.86	210.30	210.92	211.67
0.10087	4.36	4.32	4.30	4.30	209.81	210.25	210.87	211.61
0.20004	4.34	4.31	4.29	4.29	209.76	210.20	210.82	211.55
0.29996	4.33	4.30	4.28	4.28	209.72	210.16	210.77	211.50
0.40230	4.32	4.29	4.27	4.27	209.68	210.11	210.73	211.45
0.50006	4.31	4.28	4.26	4.27	209.65	210.08	210.69	211.41
0.000 mol·kg^{-1} biotin + HG								
0.00000	4.39	4.35	4.33	4.33	209.98	210.46	211.11	211.89
0.09976	4.37	4.33	4.31	4.31	209.95	210.43	211.06	211.84
0.20012	4.34	4.30	4.29	4.29	209.93	210.40	211.03	211.79
0.30214	4.31	4.28	4.27	4.28	209.91	210.37	210.99	211.75
0.39996	4.28	4.26	4.26	4.26	209.88	210.34	210.95	211.70
0.50067	4.26	4.24	4.24	4.25	209.86	210.31	210.92	211.66
0.001 mol·kg^{-1} biotin + HG								
0.00000	4.39	4.35	4.33	4.32	209.92	210.40	211.03	211.80
0.10100	4.36	4.32	4.30	4.31	209.90	210.36	210.99	211.75
0.20035	4.33	4.30	4.29	4.29	209.87	210.33	210.95	211.71
0.29989	4.30	4.27	4.26	4.27	209.85	210.31	210.92	211.66
0.40002	4.28	4.25	4.25	4.25	209.83	210.28	210.88	211.62
0.50210	4.26	4.23	4.24	4.24	209.81	210.26	210.85	211.58
0.002 mol·kg^{-1} biotin + HG								
0.00000	4.38	4.34	4.32	4.32	297.03	297.66	298.55	299.64
0.10002	4.35	4.32	4.30	4.30	296.99	297.62	298.50	299.57
0.20378	4.32	4.29	4.28	4.28	296.96	297.58	298.45	299.51
0.30087	4.30	4.27	4.26	4.26	296.93	297.55	298.40	299.45
0.39890	4.27	4.25	4.24	4.25	296.91	297.51	298.35	299.39
0.50010	4.25	4.23	4.23	4.23	296.87	297.48	298.30	299.33
0.003 mol·kg^{-1} biotin + HG								
0.00000	4.37	4.33	4.31	4.31	296.99	297.61	298.50	299.55
0.10072	4.34	4.31	4.29	4.29	296.95	297.57	298.45	299.48
0.20054	4.31	4.28	4.27	4.27	296.93	297.53	298.40	299.42
0.30341	4.29	4.26	4.25	4.25	296.90	297.49	298.35	299.36
0.40009	4.26	4.24	4.24	4.24	296.87	297.46	298.30	299.30
0.49981	4.24	4.22	4.22	4.22	296.84	297.43	298.25	299.25

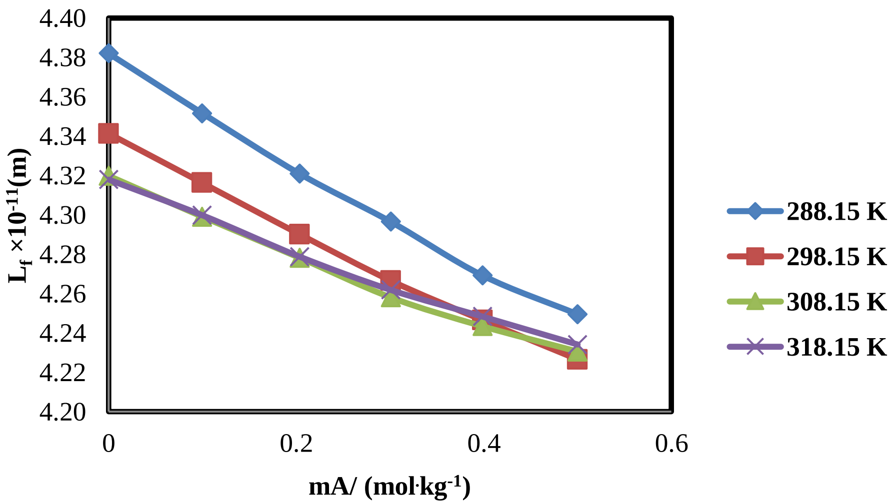

$L_f \times 10^{-11}$(m)
mA/(mol·kg^{-1})
288.15 K
298.15 K
308.15 K
318.15 K
(a)
(b)
(c)
(d)



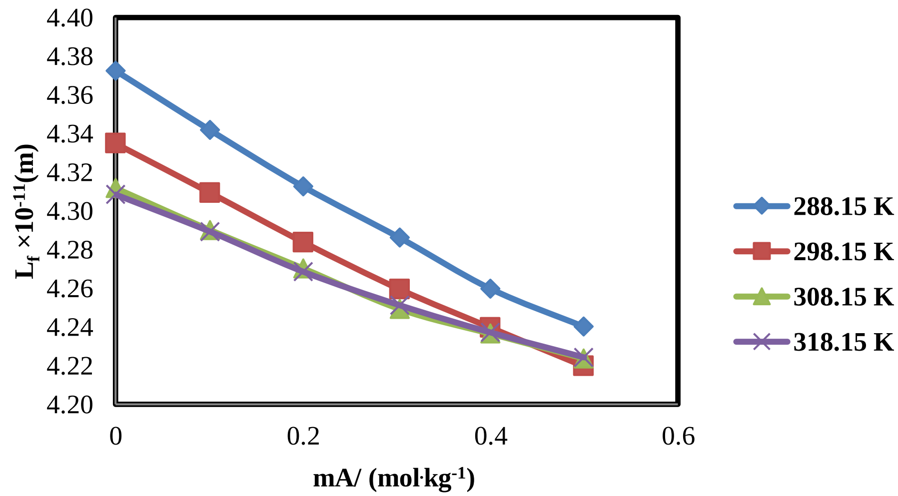
(e)



(f)

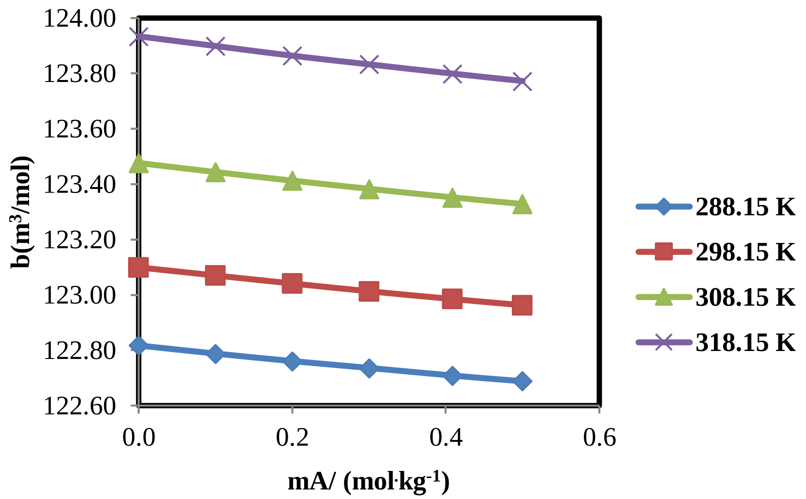


(g)



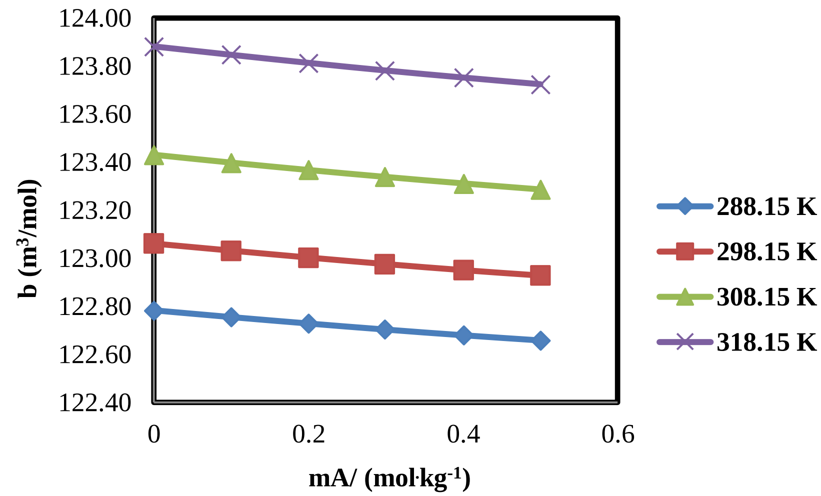
(h)

Figure 5 . Variation of Intermolecular Free Length (Lf), correspondent to the Molality(mA) of Glycols in aqueous solution of biotin. (**a**) 0.000 biotin +PG; (**b**) 0.001 biotin +PG; (**c**) 0.002 biotin +PG; (**d**) 0.003 biotin +PG; (**e**) 0.000 biotin +HG; (**f**) 0.001 biotin +HG; (**g**) 0.002 biotin + HG and (**h**) 0.003 biotin + HG opposing molality of Different Temperatures.



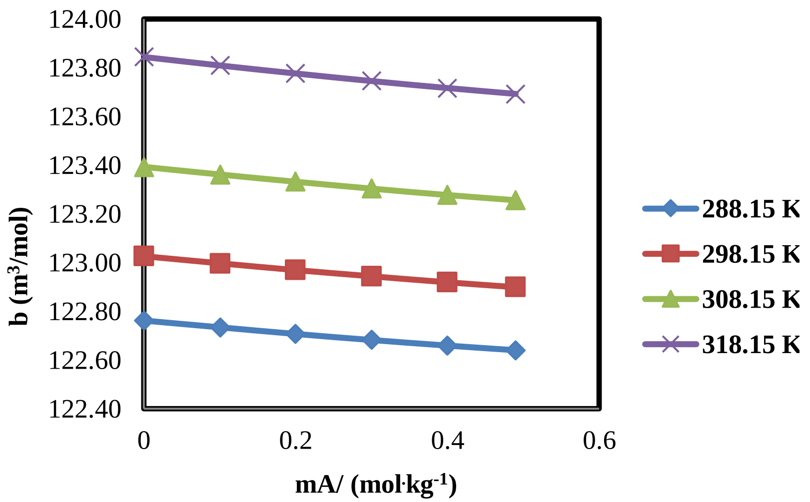
124.00
123.80
123.60
123.40
123.20
123.00
122.80
122.60
b(m³/mol)
0.0
0.2
0.4
0.6
mA/ (mol·kg⁻¹)
288.15 K
298.15 K
308.15 K
318.15 K

(a)



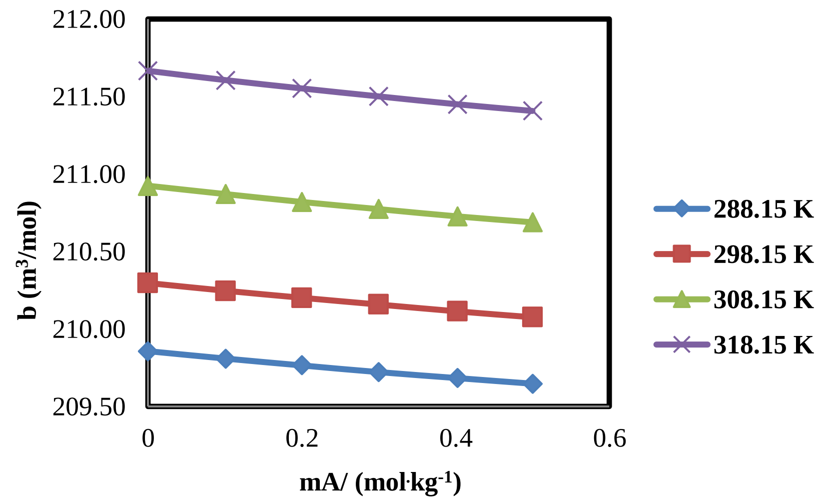
124.00
123.80
123.60
123.40
123.20
123.00
122.80
122.60
122.40
b (m³/mol)
0
0.2
0.4
0.6
mA/ (mol·kg⁻¹)
288.15 K
298.15 K
308.15 K
318.15 K

(b)



124.00
123.80
123.60
123.40
123.20
123.00
122.80
122.60
122.40
b (m³/mol)
0
0.2
0.4
0.6
mA/ (mol·kg⁻¹)
288.15 K
298.15 K
308.15 K
318.15 K

(c)



212.00
211.50
211.00
210.50
210.00
209.50
b (m³/mol)
0
0.2
0.4
0.6
mA/ (mol·kg⁻¹)
288.15 K
298.15 K
308.15 K
318.15 K

(d)

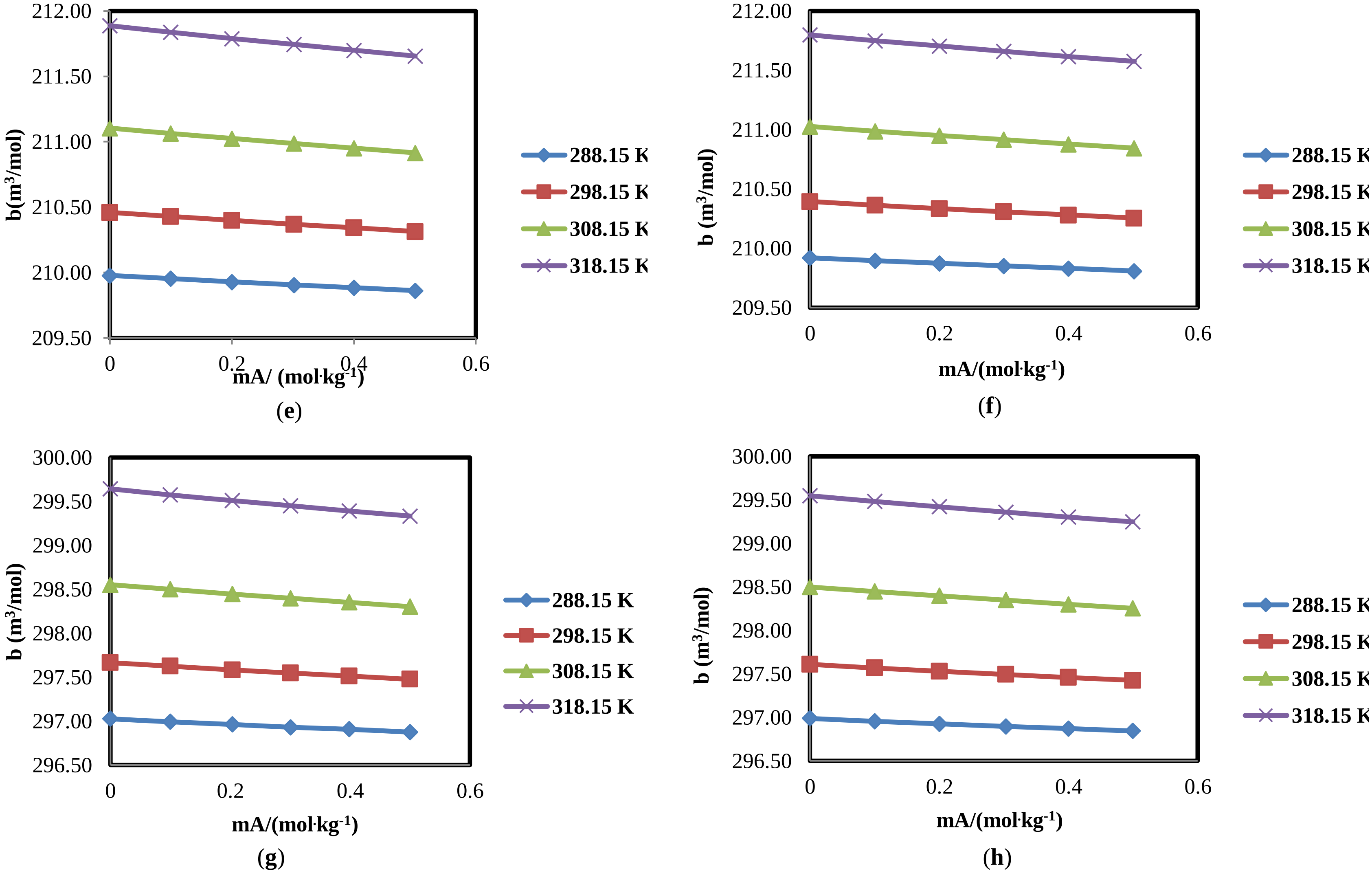


Figure 6. Variation of Vander Waal's Constant(b) correspondent to the Molality(mA) of Glycols in aqueous solution of biotin. (**a**) 0.000 biotin +PG; (**b**) 0.001 biotin +PG; (**c**) 0.002 biotin +PG; (**d**) 0.003 biotin +PG; (**e**) 0.000 biotin +HG; (**f**) 0.001 biotin +HG; (**g**) 0.002 biotin + HG and (**h**) 0.003 biotin + HG opposing molality of Different Temperatures.

3.5. Intermolecular free length (L_f).

$$L_f = K_T \times \beta^{1/2} \quad (5)$$

K_T represents Jacobson's constant.

There is strong intermolecular interaction between the molecules, as shown in Figure 5. shows that they are interacted with each other [28]. Table 3 represents intermolecular free length decreases [29-31] with increases in concentration.

3.6. Van der Waal's constant (b).

$$b = V_m\left[1 - (RT/Mc^2)\sqrt{1 + (Mc^2/3RT)} - 1\right] \quad (6)$$

V_m is molar volume, T is temperature, and R is gas constant.

From Table 3, it is obtained that Van der Waals constant decreases [32] with an increase in concentration, and the binding forces are becoming weaker [33,34], as shown in Figure 6. This resulted in weak interaction in the biotin and glycol molecules.

4. Conclusions

Density and ultrasonic velocity determines various thermo-acoustic properties in the ternary mixture containing (Biotin +water + Propylene/ Hexylene glycol) at concentrations (0.000,0.001, 0.002 and 0.003) mol·kg^{-1} and variant temperature range from (288.15, 298.15, 308.15 and 318.15) K at constant pressure 0.1 MPa. As with an increase in temperature and concentration, Acoustic impedance also increases, and this shows molecular interaction between the molecules. Rao's constant and Wada's constant show an increasing trend when both temperature and molality increase. The parameters show linear graphs, and there is no formation of complexity. Vander Waal's constant show weak interaction, as it decreases with concentration. Adiabatic compressibility and Intermolecular free length show that molecules are attracted to each other, and there is a strong solute-solvent molecular interaction in the aqueous solution.

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Conflicts of Interest

The authors declare no conflict of interest or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Chakraborty, N.; Juglan, K.C.; Kumar, H. Study of thermodynamic and acoustic properties of niacin in aqueous hexylene glycol and propylene glycol at different temperatures. *J. Am. Chem. Soc.* **2020**, *5*, 32357-32365, https://doi.org/10.1021/acsomega.0c04292.
2. Kaur, K.; Behal, I.; Juglan, K.C.; Kumar, H. Volumetric and ultrasonic studies on interactions of ethylene glycol, diethylene glycol and triethylene glycol in aqueous solutions of glycerol at temperatures T = (293.15 K - 308.15) K. *J. Chem. Thermodyn.* **2018**, *125*, 93–106, https://doi.org/10.1016/j.jct.2018.05.016.
3. Kaur, B.; Juglan, K.C. Acoustic parameter investigation of polyvinyl acetate with acetic acid using ultrasonic technique. *J. Polym. Eng.* **2013**, *33*, 851–856, https://doi.org/10.1515/polyeng-2013-0125.
4. Sharma, R.; Thakur, R.C. Study of thermodynamic and acoustic behaviour of nicotinic acid in binary aqueous mixtures of D-lactose. *AIP Conference Proceedings* **2017**, *1860*, 020054, https://doi.org/10.1063/1.4990353.
5. Kaur, P.; Chakraborty, N.; Juglan, K.C.; Kumar, H.; Singla, M. Temperature dependent physicochemical studies propylene and hexylene glycols in methanol solutions of chlorhexidine. *J. Mol. Liq.* **2021**, *339*, 116810, https://doi.org/10.1016/j.molliq.2021.116810.
6. Chakraborty, N.; Juglan, K.C.; Kumar, H. Volumetric and ultrasonic studies of molecular interactions of glycols in aqueous Niacin (vitamin B3) at different temperatures. *J. Mol. Liq.* **2021**, *332*, 115869, https://doi.org/10.1016/j.molliq.2021.115869.
7. Nayeem, S.M.; Kondaiah, M.; Sreekanth, K.; Krishna Rao, D. Acoustic and volumetric investigations in aromatic, cyclic and aliphatic ketones with dimethyl sulphoxide at 308.15 K. *Arabian J. Chem.* **2019**, *12*, 3129-3140, https://doi.org/10.1016/j.arabjc.2015.08.005.
8. Thakur, A.; Juglan, K.C.; Kumar, H.; Kaur, K. Apparent molar properties of glycols in methanol solutions of propyl 4-hydroxybenzoate (propylparaben) at *T* = (293.15 to 308.15) K: an acoustic and volumetric approach. *Phys. Chem. Liq.* **2020**, *58*, 803-819, https://doi.org/10.1080/00319104.2019.1660980.
9. Kaur. H.; Chakraborty, N.; Juglan, K.C.; Kumar H. Volumetric and acoustic behavior of PEG-200 and PEG-600 in aqueous D-Mannitol solutions at different temperatures. *J. Sol. Chem.* **2021**, *50*, 1079–1102, https://doi.org/10.1007/s10953-021-01105-3.
10. Chakraborty, N.; Juglan, K.C.; Kumar, H. Thermodynamics of various interactions in homologous series of polyethylene glycols in aqueous medium of D-panthenol at T = (288.15, 298.15, 308.15 and 318.15) K: a volumetric and acoustic approach. *Braz. J. Chem. Eng.* **2021**, https://doi.org/10.1007/s43153-021-00163-w.
11. Jain, A.; Kaur, P.; Juglan, K.C. Rheological study of reduced Graphene Oxide–Ethylene Glycol Nanosuspension for Ink. *Russ. J. Phys. Chem.* **2021**, *95*, 1671–1676, https://doi.org/10.1134/S0036024421080136.
12. Chakraborty, N.; Kaur, K.; Juglan, K.C.; Kumar, H. Volumetric and Ultrasonic Studies on Interactions of Glycols in Aqueous Solutions of Xylitol at Different Temperatures. *J. Chem. Eng. Data.* **2020**, *64*, 1435-1446, https://doi.org/10.1021/acs.jced.9b00869.
13. Jagadeesh, D.; Kumar, B. P.; Sudhakara, P.; Prasad, C.V.; Rajulu, A.V.; Song, J.I. Preparation and Properties of Propylene Glycol Plasticized Wheat Protein Isolate Novel Green Films. *J. Polym. Environ.* **2013**, *21*, 930-936, http://dx.doi.org/10.1007/s10924-013-0572-4.
14. Ashima; Juglan, K.C.; Kumar, H. Ultrasonic and volumetric behaviour of glycols with sodium ethylparaben in aqueous medium from T = 293.15 to 308.15 K at atmospheric pressure. *Results in Chemistry* **2020**, *2*, 100049, https://doi.org/10.1016/j.rechem.2020.100049.
15. Chakraborty, N.; Juglan, K.C.; Kumar, H. Volumetric and ultrasonic study of polyethylene glycols in aqueous solutions of niacin at different temperatures. *J. Chem. Thermodyn.* **2021**, *154*, 106326, https://doi.org/10.1016/j.jct.2020.106326.
16. Chakraborty, N.; Juglan, K.C.; Kumar, H. Temperature-dependent thermodynamic and physicochemical studies

of glycols in aqueous biotin solutions. *J. Mol. Liq.* **2021**, *337*, 116605, https://doi.org/10.1016/j.molliq.2021.116605.
17. Chawla, D.; Chakraborty, N.; Juglan, K.C.; Kumar, H. Temperature-dependent physicochemical studies of some glycols in aqueous d-mannitol solution. *Chemical Papers* **2021**, *75*, 1497–1506, https://doi.org/10.1007/s11696-020-01403-y.
18. Hassun, S.K. Ultrasonic study of molecular association of aqueous solutions of poly(vinyl alcohol).A method to determine molecular weight. *Eur. Polym. J.* **1988**, *24*, 795-797, https://doi.org/10.1016/0014-3057(88)90017-1.
19. Chakraborty, N.; Kumar, H.; Juglan, K.C. Volumetric and Ultrasonic Studies of Molecular Interactions of PEG 400 and PEG 4000 in aqueous niacin solutions at different temperatures. *J. Chem. Eng. Data*. **2021**, *66*, 2391-2400, https://doi.org/10.1021/acs.jced.0c01091.
20. Kumari, K, Maken, S. Topological investigation of intermolecular interactions in di-isopropylamine (DIPA) + isomeric butanol mixtures: Volumetric and acoustic properties. *J. Mol. Liq.* **2021**, *325*, 115170, https://doi.org/10.1016/j.molliq.2020.115170.
21. Nithiyanantham, S.; Palaniappan, L. Ultrasonic investigation on aqueous polysaccharide (starch) at 298.15 K. *Arabian J. Chem.* **2014**, *7*, 272- 276, https://doi.org/10.1016/j.arabjc.2010.10.030.
22. Kaur, K.; Arti, S.; Ghosh, T.K.; Banipal, T.S.; Banipal, P.K. To study the interactions between saccharide their derivatives and bactericidal cefadroxil drug: Volumetric, acoustic and molecular docking studies. *The J. Chem. Thermodyn.* **2021**, *159*, 106477, https://doi.org/10.1016/j.jct.2021.106477.
23. Gowrisankar, M.; Venkateswarlu, P.; Sivakumar, K.; Sivarambabu, S. Ultrasonic studies on Molecular Interactions in Binary Mixtures of N-MethylAniline with MethylIsobutylketone, +3Pentanone and +Cycloalkanones at 303.15 K. *J. Sol. Chem.* **2013**, *42*, 916–935, https://doi.org/10.1007/s10953-013-0003-0.
24. Kulkarni, S.S.; Khadke, U.V. Effect of Solvents on the Ultrasonic Velocity and Acoustic Parameters of Polyvinylidene Fluoride Solutions. *Ind. J. Mat. Sci*. **2016**, *2016*, https://doi.org/10.1155/2016/9582582.
25. Devi, S.; Kumar, M.; Sawhney, N.; Syal, U.; Sharma, A.K.; Sharma, M. Volumetric, acoustic and viscometric studies of L-histidine and L-serine in aqueous levofloxacin solutions at different temperatures and concentrations. *The J. Chem. Thermodyn.* **2021**, *154*, 106321, https://doi.org/10.1016/j.jct.2020.106321.
26. Sohail, M.; Rahman, H.M.; Asghar, M.N. Gatifloxacin–Ionic Surfactant Interactions: Volumetric, Acoustic, Voltammetric, and Spectroscopic Studies. *J. Surfactants Deterg.* **2021**, *24*, 327-342, https://doi.org/10.1002/jsde.12480.
27. Eyring, H.; Kincaid, J.F. Free volumes and free angle ratio of molecules in liquids. *J. Chem. Phys.* **1938**, *6*, 620-629, https://doi.org/10.1063/1.1750134.
28. Sharma, S.K.; Thakur, A. Volumetric, acoustic and viscometric studies of solute-solute and solute-solvent interactions of glycyl-glycyl-glycine in aqueous tartaric acid at different temperatures. *J. Mol. Liq.* **2021**, *322*, 114527, https://doi.org/10.1016/j.molliq.2020.114527.
29. Kumar, H.; Sharma, R.; Kumar, V.; AlMasoud, N. Volumetric and acoustic investigation of l-leucine and N-acetyl l-leucine in the aqueous solution of 1-hexyl-3-methylimidazolium bromide [HMIm][br] at different temperatures. *The J. Chem. Thermodyn.* **2021**, *158*, 106452, https://doi.org/10.1016/j.jct.2021.106452.
30. Kaur, H.; Thakur, R.C.; Kumar, H.; Katal, A. Effect of α–amino acids (glycine, l-alanine, l-valine and l-leucine) on volumetric and acoustic properties of aqueous 1-Butyl-3-propylimidazolium bromide at T= (288.15, 298.15, 308.15, 318.15) K. *The J. Chem. Thermodyn.* **2021**, *158*, 106433, https://doi.org/10.1016/j.jct.2021.106433.
31. Thakur, A.; Juglan, K.C.; Kumar, H.; Kaur, K. Investigation on molecular interaction of glycols in methanol solutions of methylparaben (methyl 4 – hydroxybenzoate) at different temperatures through thermo-acoustical analysis. *J. Mol. Liq.* **2019**, *288*, 111014, https://doi.org/10.1016/j.molliq.2019.111014.
32. Vuksanovic, J.; Soldatovic, D.; Radovic, I.; Višak, Z.; Kijevcanin, M. Thermodynamic characterization of binary mixtures of poly(propylene glycol) 425 with toluene and o-, m- and p-xylenes. *The J. Chem. Thermodyn.* **2019**, *131*, 393–403, https://doi.org/10.1016/j.jct.2018.11.020.
33. Kaur, K.; Juglan K.C.; Kumar, H. Temperature dependent physicochemical studies of polyethylene glycols (PEG-400 and PEG-4000) in aqueous sorbitol solutions, *J. Mol. Liq.* **2018**, *268*, 700-706, https://doi.org/10.1016/j.molliq.2018.07.101.
34. Ravi, S.; Amoros, J.; Arockia Jayalatha, K. Effective Method of Characterizing Specific Liquid Fluorocarbon

Interactions using Ultrasound, *J. Phys. Chem. B.* **2008**, *112*, 6420–6425, https://doi.org/10.1021/jp800812c.