Determination of Properties of Hexadecane and Butanol Mixtures Using Extrinsic Fiber Optic Chemical Sensor at Various Wavelengths

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ABSTRACT:
Refractive Index is the most important property of the substances irrespective of its state of existance. The study of Refractive Index of many chemicals, oils of several plants, bio fluids are very impartment to scientists, chemists and researchers. Several methods have been developed to study the Refractive Index of liquids as mentioned in literature. In the present paper it is proposed to develop a chemically sensitive and cost effective U – shaped glass probe based fiber optic sensor to study the Refractive Index of Hexadecane mixed with Butanol at room temperature. In the present work the Densities and Refractive Indices of pure chemicals i.e., Hexadecane and Butanol and that of binary solutions of Hexadecane mixed with Butanol were determined experimentally. The other chemical parameters like Molar Volume, Molar Refraction and Dielectric Constant for each binary chemical mixtures with different ratios were calculated from the measured values of Refractive Indices and Densities. Intensity modulated evanescent wave U-shaped glass probe fiber optic sensor is developed to study the properties of Hexadecane mixed with Butanol at various wavelengths such as 630nm, 660nm, 820nm and 850nm.

Keywords: Butanol, Dielectric Constant, Hexadecane, Molar Refraction, Molar Volume, Molefraction, Refractive Index, U – shaped glass probe.

I. INTRODUCTION

To understand the molecular interactions and inherent properties of chemicals, it is very important to know the intensive properties like density, refractive index and constitutive properties like dielectric constant, molar refraction, molar volume and molefraction. The studies of index of refraction is mainly used as a tool for investigation of the physical properties of pure components and the nature of intermolecular interaction between the chemical mixtures [1–3]. The constitutive properties like molar volume, molar refraction, etc. are very useful to understand the intermolecular interaction between like and unlike molecules, atoms and to understand the nature and structure of the molecules. Fiber optic chemical sensors with various sensing mechanisms and different sensor designs for the detection of refractive index, pH measurements, concentration of solutions etc. are reported in the literature [4–14]. The quality of the fiber is decided by the transparency of the glass to prepare the fiber. Several sensors developed in the recent past have made use of optical fibers fabricated from high quality glasses [15–16]. Fiber optic sensors can be classified as intensity modulated fiber optic sensors, interferomatric fiber optic sensors, phase modulated fiber optic sensors and wavelength modulated fiber optic sensors. The intensity modulated fiber optic sensors occupy the major part of the fiber optic sensors [17–19]. In the present work it is proposed to develop intensity modulated PCS fiber optic chemical sensor to determine the properties of Hexadecane and Butanol mixtures at room temperature using various wavelengths i.e., 630nm, 660nm, 820nm and 850nm.

II. EXPERIMENTAL ARRANGEMENT

A U – shaped glass probe prepared from borosilicate glass was used in the present work as sensing element with the following geometrical parameters [fig.1–2].

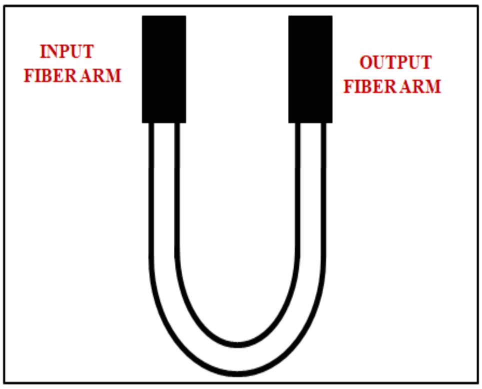
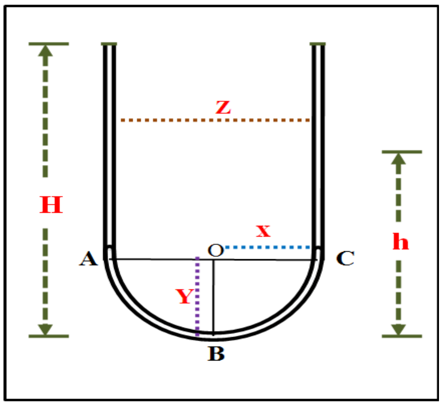


Fig.–1: U–Shaped Glass Rod



Thickness of rod:	0.5mm
Total height of the glass rod(H):	40mm
Height of the glass rod immersed in liquid(h):	30mm
Width between two prongs(Z):	5mm
Radius of the Curvature(X):	2.5mm
Depth of the Curvature(Y):	2.5mm

Fig.–2: Geometrical Parameters of U-shaped Glass Rod

The basic components of experiment consisting of mainly three components they are 1.Light source, 2.Benchmark optical power detector, 3.Two PCS optical fibers consisting of sensing zone (U-shaped glass rod). In the experimental arrangement two PCS step-index multimode optical fibers of 200/230μm diameters of core and cladding respectively and 50cm length each with SMA connector in which one used as input fiber and other used as output fiber. Four kinds of light sources are used in the present experimentation operating at wavelengths of 620nm, 660nm, 820nm and 850nm. At the output end of the sensor system a suitable power meter is used to read the output power coming from various inputs of light sources. Initially, the light is launched from a source into the input end of a plastic clad silica fiber (PCS) which inturn connected to one end of the U – shaped glass rod and the light emitted from other end of the glass rod is being coupled to output end of the PCS fiber which inturn connected to a power meter. At each coupling point i.e. coupling of fiber to glass rod and fiber to the terminal equipment an enough care is taken that no light is escapes out at the joints. Index matching glue that is available in the market is used for proper sealing and which was covered with M-Seal and insulation tape for additional precaution at each end of U – shaped rod. Suitable SMA connector is used at the point of launching the light from source into the input fiber arm. A similar care was taken in connecting the output fiber arm to the power meter. Thus the experimental arrangement is made ready for the experimentation to be carried out. Suitable stands were used to place both light source and light detector in the arrangement. The Experimental arrangement is shown in Fig. [3].

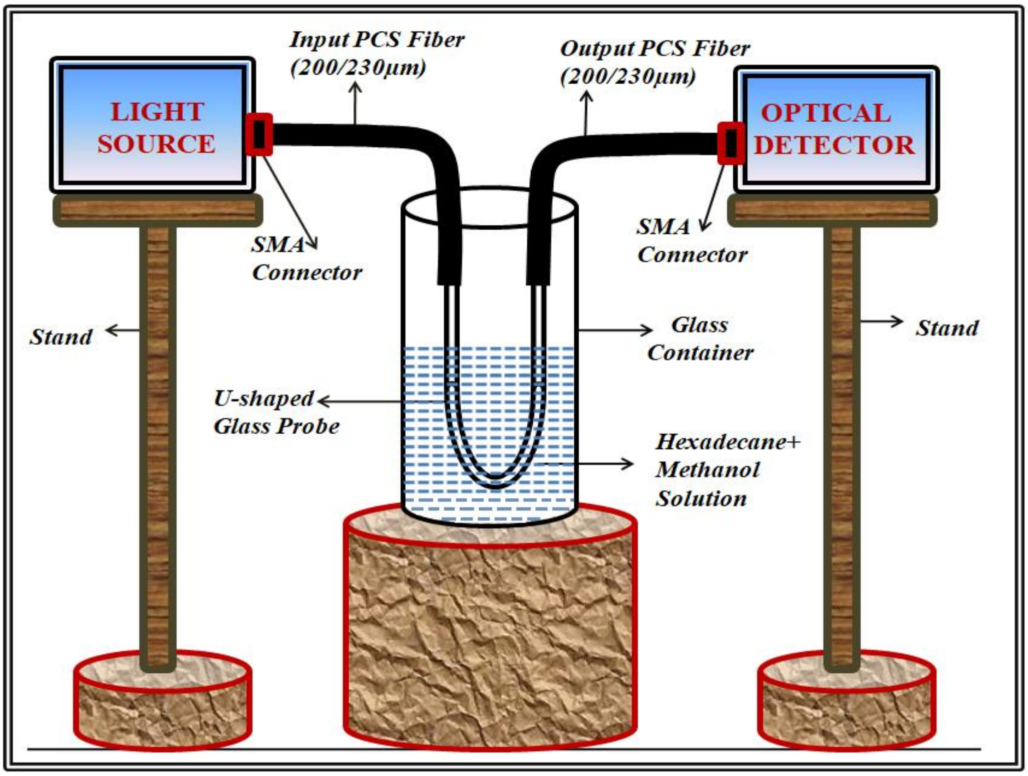


Fig.–3: Experimental arrangement of Intensity Modulated Extrinsic Fiber Optic Chemical Sensor

III. EXPERIMENTAL DETAILS

Initially the binary mixture of Hexadecane and Butanol of various ratios making the total volume of the mixture always equal to 10ml is prepared and the refractive index of each mixture is measured by using Digital Refractometer (RX 7000i). The chemical mixture so prepared is poured into the glass beaker and the U- shaped glass rod is immersed into it. Light is lunched from the source which is operated at 630nm wavelength into the input fiber end and collected through output fiber end which travels through U- shaped glass rod. Due to the absorbing property of the liquid surrounding the U- shaped glass probe, some amount of the light enters into the liquid and accordingly the light collected at the output end will be decreased. The R.I. values and output power values are tabulated. The experiment is repeated for various mixture of Butanol mixed in Hexadecane having

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different R.I. values. It is noticed that as mole fraction of the Butanol in Hexadecane increases, the power output also increases as expected. At the same time it is observed that as R.I. value of binary mixtures decreases, the output power increases. The experiment was repeated with other light sources which are operated at 660nm, 820nm and 850nm.

Standard chemical parameter of Hexadecane and Butanol

	Hexadecane	**Butanol**
Molar Mass (g/mole)	226.45	74.12
Refractive index(n)	1.4329 at 20□	1.3993 at 20□
Density (g/ml)	0.7701	0.8098
Color	Colorless	Colorless
Boiling Point	286.9□	117.6 □
Melting Point	18.18□	-88.6□
Molar Volume (c.c./mole)	294.0527	91.5288
Molar Refraction (c.c./mole)	76.4075	22.1538
Dielectric Constant(K or $\varepsilon_r = n^2$)	2.0532	1.9580

IV. RESULTS AND DISCUSSION

The experiment is initially started by using light source operating at a wavelength of 630nm by exposing the U-shaped glass rod to the binary mixture of different ratios one after the other, the output power noted at each time and was recorded. The experiment is repeated by using various light sources operating at wavelengths of 660nm, 820nm and 850nm. The variation of output power with refractive index are recoded and represented graphically in Fig. [4]

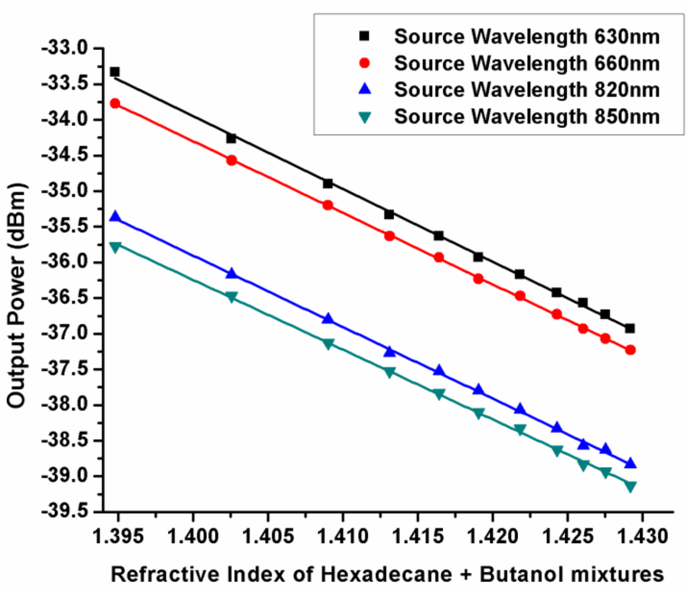

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Fig.-4: Relation between Refractive Index Vs Output Power(dBm) of Hexadecane + Butanol mixtures

The relationship between power loss and the refractive index of the liquid cladding is presented graphically in Fig. [5].

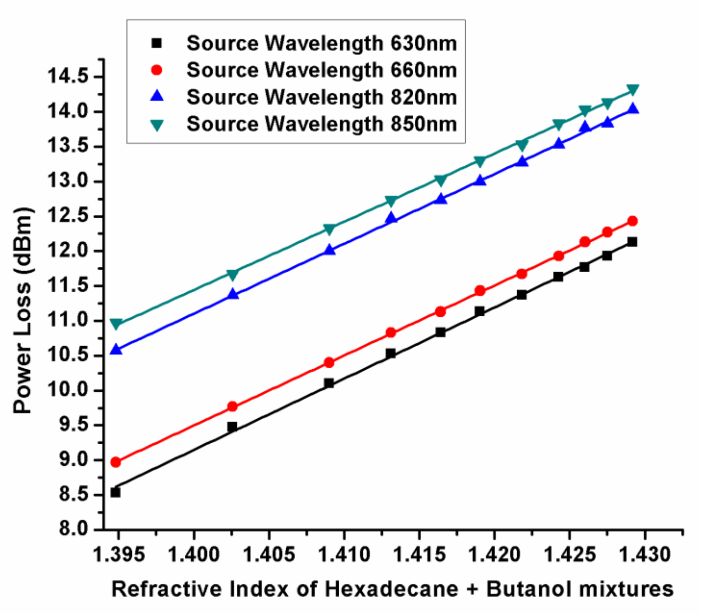

Fig.-5: Relation between Refractive Index Vs Power Loss(dBm) of Hexadecane + Butanol mixtures

Similarly the relationship between density of liquid vs output power and power loss is shown in Fig. [6–7].

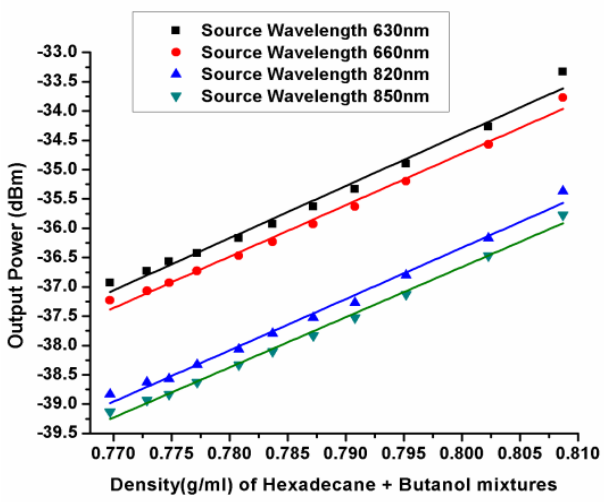

Fig.-6: Relation between Density(g/ml) Vs Output Power(dBm) of Hexadecane + Butanol mixtures

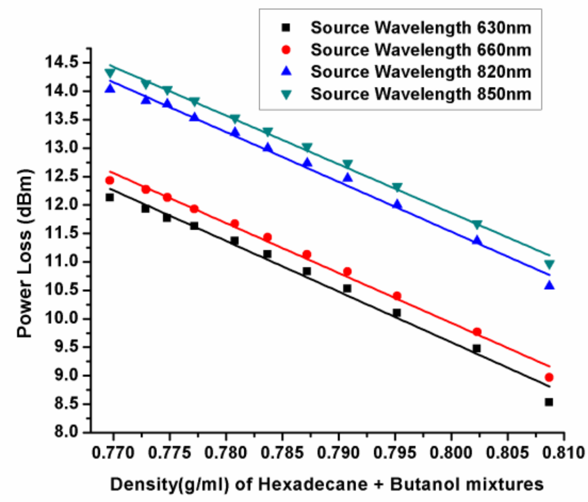

Fig.-7: Relation between Density(g/ml) Vs Power Loss(dBm) of Hexadecane + Butanol mixtures

With the help of measured values of density, refractive index the other chemical properties like molar volume, molar refraction, dielectric constant and molefraction of Hexadecane and Butanol mixtures have been calculated and relation between output power Vs molar volume, molar refraction, dielectric constant and molefraction were plotted and similar relation is established with power loss Vs molar volume, molar refraction, dielectric constant and molefraction and all have been shown graphically in Fig.[8–13]. Finally molefraction of Hexadecane and Butanol in Hexadecane and Butanol mixtures is calculated and relation with refractive index is plotted graphically in Fig. [14].

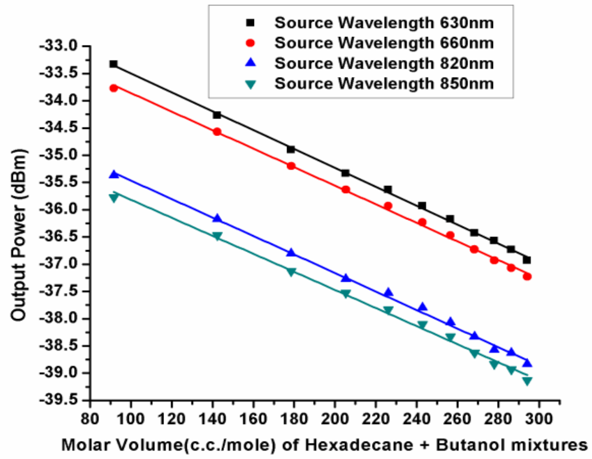

Fig.-8: Relation between Molar Voume (c.c./mole) Vs Output Power(dBm) of Hexadecane + Butanol mixtures

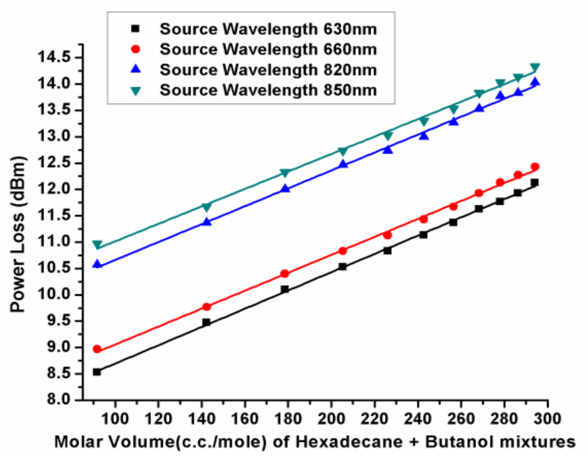

Fig.-9: Relation between Molar Volume (c.c./mole) Vs Power Loss(dBm) of Hexadecane + Butanol mixtures

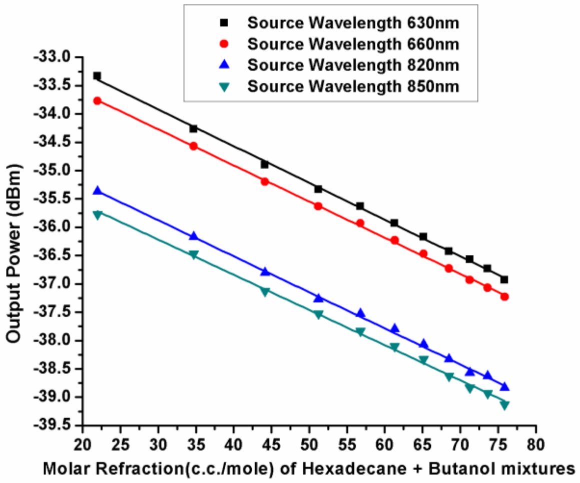

Fig.-10: Relation between Molar Refraction (c.c./mole) Vs Output Power(dBm) of Hexadecane + Butanol mixtures

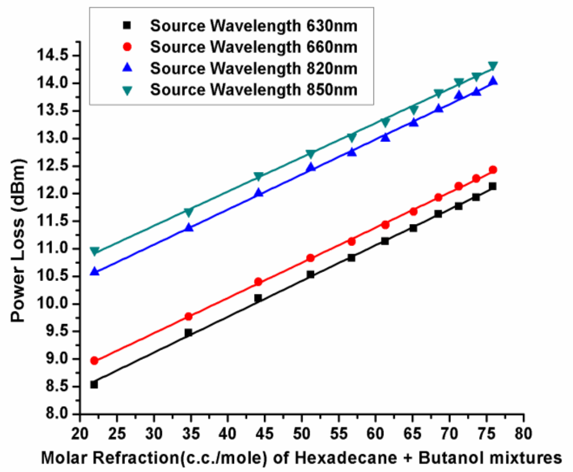

Fig.-11: Relation between Molar Refraction (c.c./mole) Vs Power Loss(dBm) of Hexadecane + Butanol mixtures

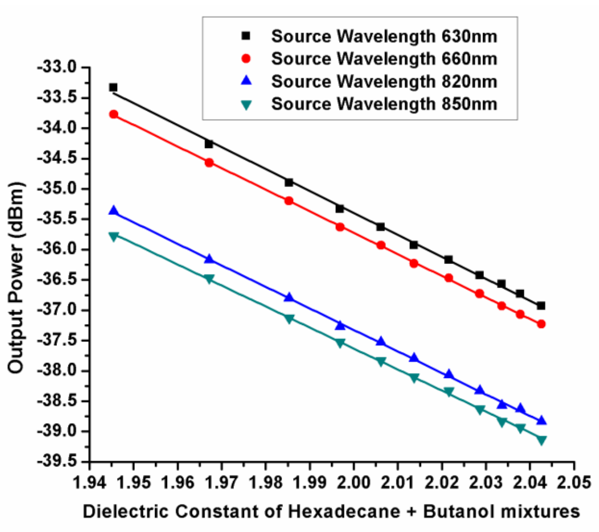

Fig.-12: Relation between Dielectric Constant Vs Output Power(dBm) of Hexadecane + Butanol mixtures

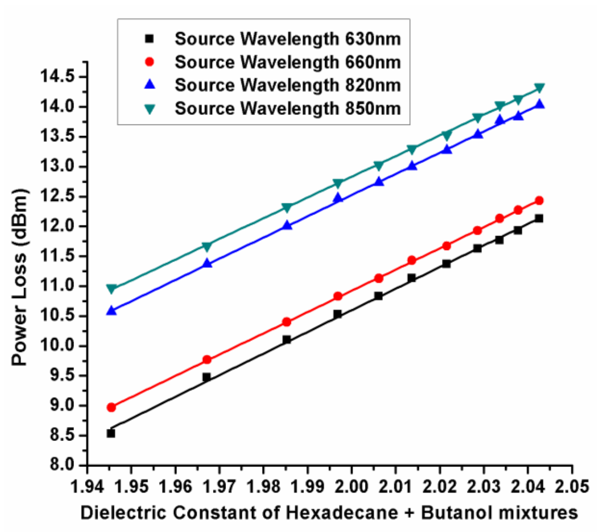

Fig.-13: Relation between Dielectric Constant Vs Power Loss(dBm) of Hexadecane + Butanol mixtures

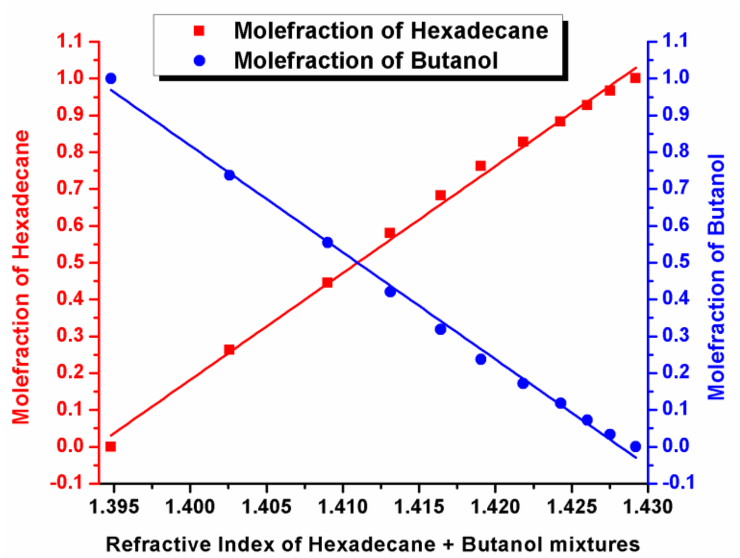

Fig.-14: Relation between Refractive Index Vs Molefraction of Hexadecane, Butanol in Hexadecane + Butanol mixtures

IV. CONCLUSION

It is concluded that from the above study as the concentration of Butanol in the binary mixture (Hexadecane + Butanol) increases, the refractive index of the guiding liquid also increases. It is also observed that for all the wavelengths (620nm, 660nm, 820nm & 850nm) with increasing the index of refraction of guiding medium the output power decreases and hence power loss increases. The graph showing the variation of output power with the variation of the refractive index of the guiding liquid can be used as calibration curves to measure the refractive index of the unknown transparent liquids in the dynamic range of 1.394 nD to 1.430 nD at room temperature.

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