Zaiput Flow Technologies

Membranes for Liquid-Liquid Separators

Providing in-line liquid-liquid separation for flow chemistry

Selection Guide

A variety of membranes for your Zaiput separator are available to optimize separation performance and throughput. Membranes are available in both hydrophobic and hydrophilic, they are low cost and easy to replace.

Membrane selection process

The key parameters for identifying a suitable membrane for separation are the interfacial tension (IFT) between the two phases and the viscosity of the permeating phase (higher viscosities will decrease the throughput of the device).

In general, the lower the interfacial tension, the smaller the pore size needs to be. However, smaller pore size reduces the maximum viscosity that can be accommodated by the membrane. A smaller pore size also lowers the total throughput of the device.

For general applications, we recommend using a hydrophobic membrane and following the steps below:

1. **Identify your mixture's interfacial tension.** Interfacial tension data for a variety of solvent systems is available at the end of this document, in literature or can be searched for online. For complex mixtures, an initial approximation can be obtained by looking at the interfacial tension between the largest component of your system. Please note that salts give a modest increase to the interfacial tension and solvents miscible in both aqueous or organic will decrease it. Often a good estimate is enough, a more accurate value is helpful when dealing with low interfacial tension systems (<5 mN/m).
2. **Know the viscosity of the permeating phase.** Usually an estimate of the viscosity of your permeating phase (organic for a hydrophobic membrane) is enough. Data can be found at the end of this document, in literature, on our website or on the web. A more accurate value can be helpful for detailed assessment of maximum device throughput at production scale.
3. **Locate the values on the graph.** Figures 1 and 2 are a plot of the organic's viscosity (permeating phase) vs. interfacial tension with the aqueous. The colored regions indicate what membrane is suitable in each range of the parameters (Fig.2 shows details of Fig 1 for low values of viscosity). Use the values of viscosity and interfacial tensions of your systems to identify the adequate membrane for your case. If your system falls near the boundary of a colored area, selecting the smaller pore size membrane may save some trial time.
4. **What to do if you don't have the IFT or viscosity available.** If you don't know the interfacial tension and/or viscosity of your system, or you have a complex solvent system which makes it hard to determine, you can use the troubleshooting guide on page 4. This guide is also helpful if your first membrane selection using the above process wasn't successful.
    - If you have issues or continue to have unsuccessful separations, please contact Zaiput

Important Notes

- ⇒ ***80% of separations will be successfully carried out with the OB-900 (medium pore size) membrane that is installed on your device at the time of assembly.***
- ⇒ ***Larger pore sizes (OB-2000) are meant to be used for more viscous organics (light oils, essential oils, etc) or to increase device throughput for production needs.***
- ⇒ ***When using a hydrophilic membrane, always prewet the membrane with DI water or your aqueous for consistent results***
- ⇒ ***If you have solids present in the permeating phase or at the interface, they may cause retention over time and***

Selecting a Hydrophobic Membrane

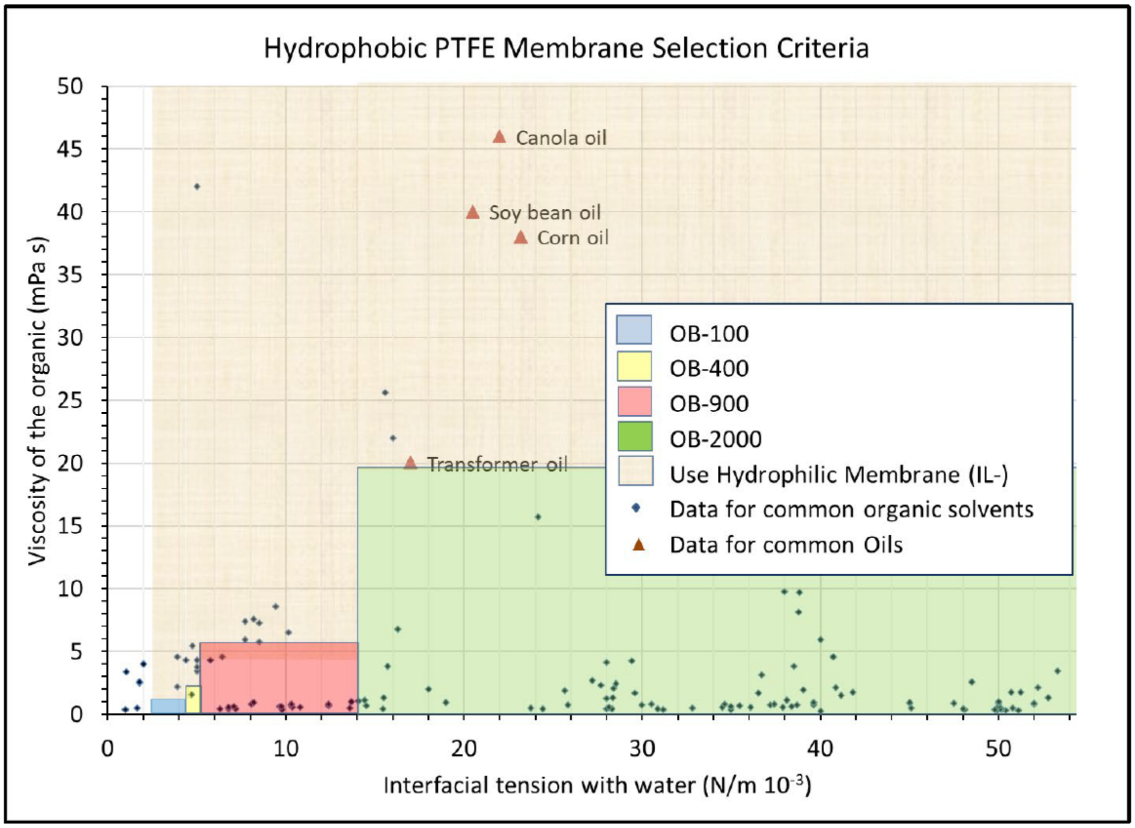


Fig 1—Membrane selection chart. *Locate your liquid-liquid system on the chart to find out the rec-*

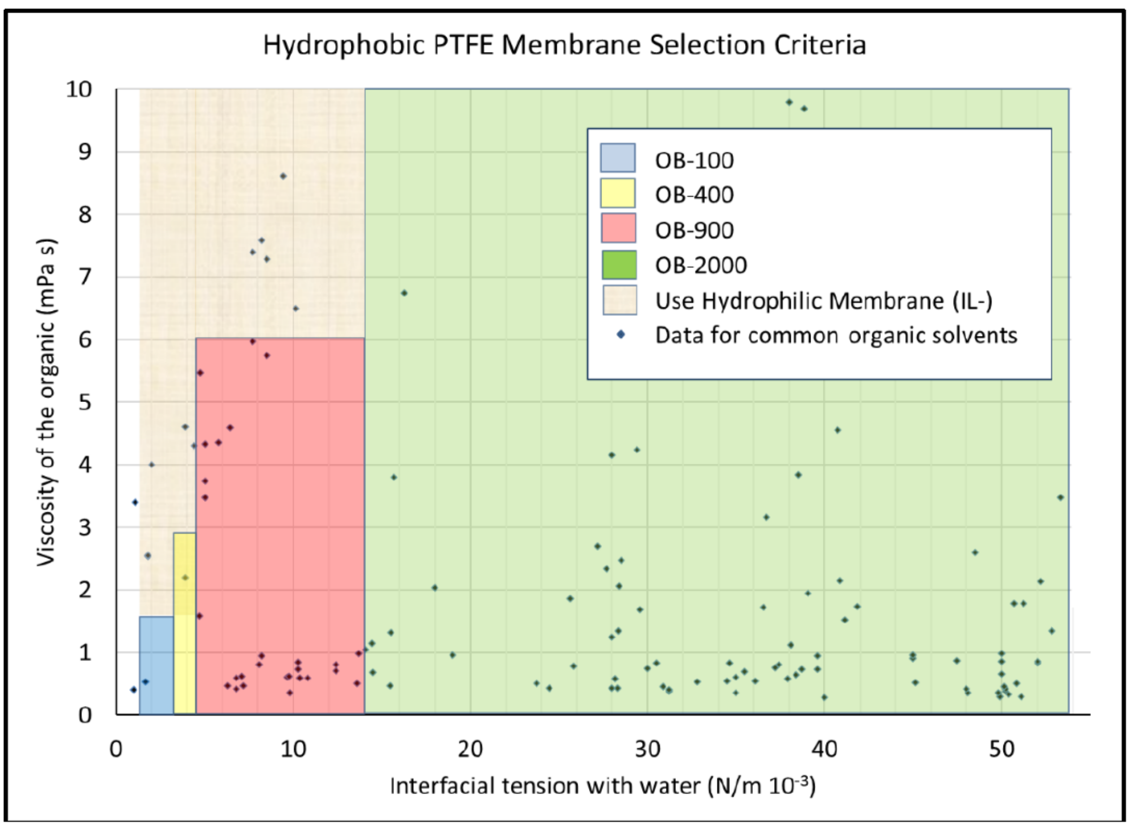


Fig 2—Membrane selection chart. Expanded view of low viscosity values of box in Fig 1.

Selecting a Hydrophilic Membrane

Hydrophilic membranes are recommended in the following cases:

- There is an emulsion with aqueous as the dispersing medium (see page 5 for further information).
- There is a large aqueous: organic phase ratio.
- For gas-liquid separations between an aqueous phase and a gas phase. Best results are obtained when the aqueous is the permeating phase and gas retained.
- When there is a high viscosity organic with low interfacial tension. In this case the small pore size hydrophobic membrane may not be able to accommodate the flow of a viscous organic; if the aqueous has low viscosity the removal of the aqueous can address this type of separation.

For selection of a hydrophilic membrane, the steps are the same as described for hydrophobic membranes, except Figure 3 should be used instead of Figure 1 and Figure 2.

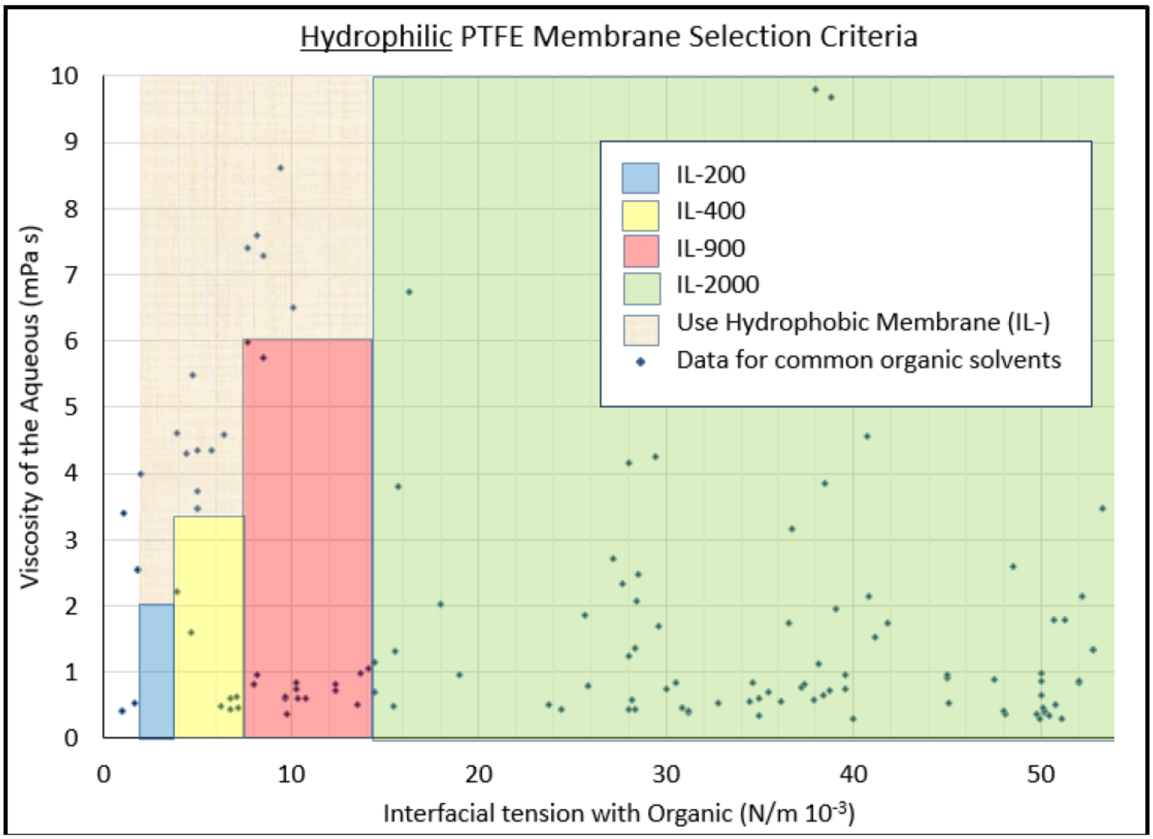


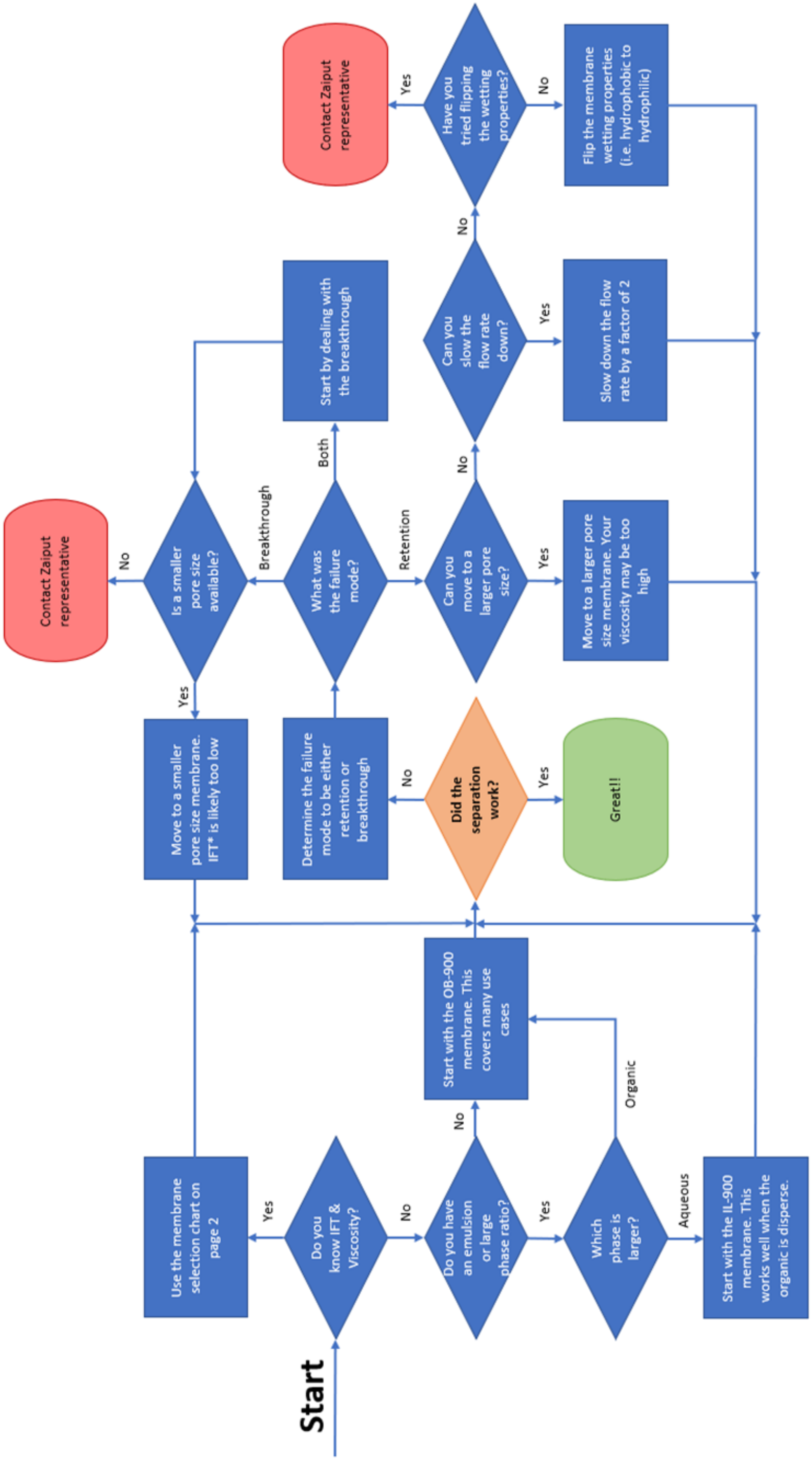
Fig 3—Hydrophilic membrane selection chart. *Locate your liquid-liquid system on the chart to find out the recommended membrane pore size. Dots represent values of viscosity, interfacial tension with water of common solvents used in organic chemistry.*

Membrane Lifetime

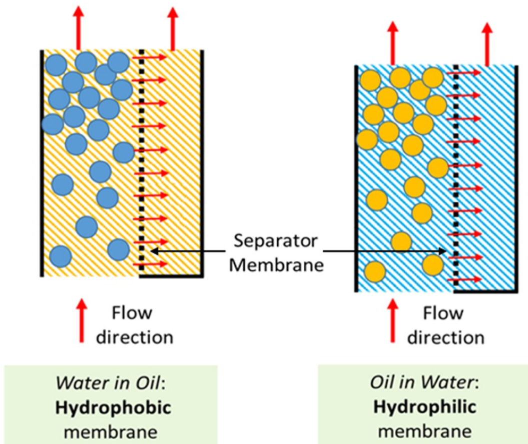
Membranes are sturdy and usually do not tear. Over time they may foul if the permeating liquid carries particulates; this typically results in some loss of permeating area and hence some retention is observed where normally a complete separation can be obtained ("retention" means that permeating phase is found – *retained*- with the non permeating phase).

While exact membrane lifetime may change drastically depending on conditions of use, we have experienced that in pharmaceutical applications a membrane's lifetime is typically from a few days to a couple of weeks.

Troubleshooting Guide



Separation of Emulsions



Emulsions are typically separated very well with our devices. Best performance is achieved when the wetting phase is the dispersing medium of the emulsions.

In other words, emulsions can be of two main types: :

- "*oil in water*", separated best with a hydrophilic membrane
- "*water in oil*", separated best with a hydrophobic membrane

The general idea is to remove the dispersing medium to foster coalescence of the dispersed one. Contact us for more information.

Specific Membrane Ordering Information

Membrane Part Number is structured in the following way:

XX-XXX - S XX

e.g. - **OB-100-S10**
IL -400-S200

Wetting Phase (OB/IL)

- OB = Hydrophobic
- IL = Hydrophilic

Pore Size Selection

- 100 / 200 Very Small (OB/IL)
- 400 Small (OB/IL)
- 900 Medium (OB/IL)
- 2000 Large (OB/IL)

Instrument

- 10 = SEP-10
- 200 = SEP-200
- 3000 = SEP-3000

⇒ **Membrane Sampler Package : MEM-10: Includes a set of every membrane variety at a discount.**

Contact

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- **Zaiput Flow Technologies**, an MIT spin-out, is focused on bringing innovative separation technology and related tools to market.
- We are looking forward to answering your questions, addressing your support needs, or to discussing your application.

Viscosity and interfacial tension with water for many organic solvents

Solvent	Interfacial Tension (mN/m)	Dynamic viscosity (mPa.s) or (cP)
1,1,2,2-Tetrabromoethane	38.82	9.69
1,1,2-Trichloroethane	29.60	1.69
1,1-dichloroacetone	14.43	1.14
1,2,3-tribromopropane	38.50	3.84
1,2-Dibromoethane	36.54	1.73
1,2-Dichloroethane	30.50	0.84
12-hydroxy-9-octadecenoic acid	14.25	107.00
1-Butanol	1.80	2.54
1-Chloro-2-Methylpropane (isobutyl chloride)	24.43	0.43
1-Chloro-3-Methylbutane (isoamyl chloride)	15.44	0.47
1-Heptyne	28.15	0.58
1-hexanol	6.80	0.59
1-Octanol	8.52	7.29
1-Octene	50.00	0.66
2,2,4- Trimethyl Pentane	50.10	0.46
2,2'-dichlordiethyl ether	28.40	2.07
2,2'-dichlorodiethyl sulfide	28.36	1.35
2,2-Dimethyl Butane	35.00	0.35
2,3-Dichloropropene	45.10	0.52
2,3-Dimethyl Butane	49.80	0.36
2-Butanone	1.00	0.40
2-Chloro-2-Methylpropane (t-butyl chloride)	23.75	0.51
2-Heptanone	12.40	0.71
2-Hexanone	9.73	0.62
2-Methyl-2-Butene	36.69	3.16
2-Octanol	9.42	8.61
2-Octanone	14.09	1.04
2-Pentanol	5.00	3.47
2-Pentanone	6.30	0.47
3,3-dimethyl 2 butanone (methyl t-butyl ketone)	10.81	0.59
3-hexanone	13.58	0.51
3-Methyl Hexane	50.40	0.33
3-Methyl Pentane	49.90	0.29
3-Methyl-1-butanol	5.00	3.74
9-Undecenoic Acid	10.14	6.50
a-Bromonapthalene	42.07	16.20
a-chloronapthalene	40.74	4.55
Amyl Acetate	50.00	0.86
Aniline	5.77	4.35
Anisole (methyl phenyl ether)	25.82	0.78
Benzaldehyde	15.51	1.32

Viscosity and interfacial tension with water for many organic solvents

Benzene	35.00	0.60
Benzonitrile	28.00	1.25
Benzyl Alcohol	4.75	5.47
Bromobenzene	38.10	1.12
Bromoethane	31.20	0.38
Butyl Acetate	57.00	0.69
Butyl Benzaoate	28.00	4.15
Butyronitrile (propyl cyanide)	10.38	0.60
Carbon Disulfide	48.10	0.36
Carbon Tetrachloride	45.00	0.91
Chloroacetone	7.11	0.62
Chlorobenzene	37.41	0.81
Chloroform	32.80	0.53
Chloromethane (Methyl Chloride)	50.00	0.27
Cis-decalin	51.24	1.78
Cyclohexane	50.00	0.98
Cyclohexanol	3.90	4.60
Cyclohexanone	3.90	2.20
Cyclopentane	48.00	0.41
Decane	52.00	0.86
Dibutyl Amine	10.30	0.85
Dibutyl Ether	30.00	0.74
Dibutyl-3,3'-dimethyl amine (diisoamyl amine)	13.51	
Dichloromethane	28.31	0.43
Diethyl Adipate	18.00	2.03
Diethyl Dimethylmalonate	19.00	0.96
Diethyl Ether	10.70	0.24
Diiodomethane	48.50	2.60
Diisobutyl Amine	10.28	0.74
Diisopropyl Ether	17.10	0.27
Dimethyl Acetamide	8.20	0.95
Dimethyl Formamide	8.05	0.80
Dimethylamine	1.06	3.40
Dimethylsulfoxide (DMSO)	28.52	2.47
Dioxane	3.86	0.01
Dipropyl Amine	1.66	0.53
Dodecane	52.80	1.34
Ethanethiol	26.12	0.22
Ethyl Acetate	6.80	0.42
Ethyl Bromide	31.20	0.40
Ethylbenzene	38.40	0.64
Furfural	4.70	1.59
Heptanal (n-heptaldehyde)	13.70	0.98
Heptane	50.20	0.38
Heptanol	7.70	7.40
Hexadecane	53.30	3.47

Viscosity and interfacial tension with water for many organic solvents

Hexane	51.10	0.30
I-Butanol (Isobutyl alcohol)	2.00	4.00
I-Hexane	40.00	0.28
Iodobenzene (Phenyl Iodide)	41.84	1.74
Iodoethane	40.00	5.93
I-Pentane (Isopentane)	48.70	0.23
I-Pentanol (Isoamyl alcohol)	5.00	4.33
Isobutyraldehyde	7.20	0.47
Isopentyl Nitrate	30.88	0.46
Mesitylene (1,3,5-trimethylbenzene)	38.70	0.73
Methyl Amyl Ketone	12.40	0.81
Methyl Ethyl Ketone (butanone)	1.00	0.40
Methyl Tert Butyl Ether (MTBE)	9.80	0.36
Methyl Isobutyl Ketone	15.70	3.80
Methylene Chloride	28.00	0.43
m-nitrotoluene	27.68	2.33
M-Xylene	37.90	0.58
N,N-Diethyl-1-naphtylamine	16.00	22.00
n-Amyl Alcohol	4.40	4.30
N-Butanol	1.80	2.54
N-Butyl Acetate	14.50	0.69
n-Butyl Alcohol	1.80	2.54
N-Butylbenzene	39.60	0.95
N-Decane	52.00	0.84
N-Dodecane	52.80	1.34
N-Heptane	50.20	0.41
N-Heptanol (1-heptanol)	7.70	5.97
N-Hexanol	6.44	4.59
Nitrobenzene	25.66	1.86
Nitromethane	9.66	0.61
N-Octanol	8.19	7.59
N-Pentanol	5.00	3.47
o-Bromotoluene	41.15	1.52
Octane	50.81	0.51
Octanoic Acid	8.50	5.74
Oleic Acid	15.59	25.60
Olive Oil	24.17	15.70
o-nitrotoluene (methylnitrobenzene)	27.19	2.70
P-cymene (1-methyl-4-isopropylbenzene)	34.61	0.83
Pentane	49.00	0.24
Perfluorohexane	38.00	9.79
Phenetole	29.40	4.24
Phenyl isothiocyanoate	39.04	1.95
Phthalic Acid diethyl ester	16.27	6.75
Polypropylene glycol-2000	5.00	42.00
Propylbenzene	39.60	0.74

Viscosity and interfacial tension with water for many organic solvents

Stryene (vinylbenzene)	35.48	0.70
Tetrabromoethane	38.80	8.15
Tetrachloroethylene	47.48	0.87
Tetrachloromethane (carbon tetrachloride)	45.00	0.96
Tetradecane	52.20	2.13
Toluene	36.10	0.55
Trans-decalin	50.70	1.79
Tribromomethane (bromoform)	40.85	2.15
Trichloroethylene	34.50	0.55
Xylene	37.20	0.76