Solubility in Liquids

Most people are familiar with the "like dissolves like" rule. Water and oil do not, but water and ethanol do. And perfluorocarbons do not mix with any of them.

The miscibility of two liquids (like all chemical and physical processes) depends on the second law of thermodynamics, which is best expressed as the Gibb's equation; if the ΔG term is negative, the process can proceed:

$$\Delta G = \Delta H - T\Delta S$$

The value of ΔG depends partly on the temperature and the entropy, $T\Delta S$. For mixing, the entropy will always increase, ΔS is always positive. This is the impetus for mixing, and we can note that mixing is more likely if T is higher.

The other term is ΔH, the energy change during mixing, and it is here that we see the big difference between different pairs of liquids. ΔH is usually positive, but as long as it is only small, the $T\Delta S$ will be bigger, and mixing will occur. So how big will ΔH be?

Conceptually, the energy change, ΔH, can be broken into three parts, the energy required to pull apart the molecules in liquid A, ΔH_{dA}, the energy required to pull apart the molecules in liquid B, ΔH_{dB} and the energy we get back when we put the molecules altogether, ΔH_M.

$$\Delta H = \Delta H_{dA} + \Delta H_{dB} - \Delta H_M$$

What this comes down to is that if it takes a lot of energy to pull apart the molecules in liquid A, and you do not get much energy back when yo put all the molecules of the two liquids back together, then ΔH will be high, and the liquids will not mix.

For example, water and oil do not mix because the intermolecular bonding between water molecules is very strong. It takes a lot of energy to pull apart the water molecules, because there is a strong attraction between them

Ethanol, however, will mix with water, because ethanol also has strong intermolecular bonds – not as strong as water, but comparable. When the ethanol mixes, it breaks strong intermolecular bonds in the water, but makes new strong bonds between the water and the ethanol (with a little help from entropy).

In a perfluorocarbon there are next to no bonds between molecules, and next to no energy required to break the bonds. Conversely, there will be next to no energy recovered when mixing with the solvent.

Solubility of FLUTEC™ liquids in various solvents

Quoted as g per 100 g of solvent at 25ºC (0º for PFP)

FLUTEC™ liquid	PFP	PFH	PMCH	m-PDCH	PFD	PFMD
Formula	$CF_3(CF_2)_3CF_3$	$CF_3(CF_2)_4CF_3$	$C_6F_{11}CF_3$	$C_6F_{10}(CF_3)_2$	$C_{10}F_{18}$	$C_{10}F_{17}CF_3$
Acetone	4.2	8.6	9.0	8.0	3.8	3.7
Aniline				<0.5	<0.5	<0.5
Benzene		5.0	6.6	5.4	5.8	5.9
Carbon tetrachloride	6.7	11.0	39	21	31	19
Chlorobenzene		4.7		2.9		1.6
Chloroform	3.6	8.4	11	8.6	3.8	7.3
Cyclohexane		12				9.5
Cyclohexanone				1 5		
Diethylether					Misc	
Dimethylformamide		3.4		1.5		<0.8
Dimethylsulphoxide		2.0		<0.7		<0.8
Ethyl acetate		10.7		8.8		6.3
Ethyl alcohol	4.2	4.3	5.7	3.5	1.9	2.5
Ethylbenzene	3.0	2.9	6.3	4.3	5.8	3.4
Ethylene glycol		<0.7		<0.7		<0.7
'Halothane'	Misc	Misc	Misc	Misc	Misc	Misc
Heptane	25	34	Misc	55	29	39
Hexane		Misc		Misc		56
Kerosene		4.7		2.2		2.4
Methylalcohol	3.1	4.3	2.3	1.2	1.9	<1.0
Methylcyclohexane		16.0		16.8		11.8
Methylethylketone		8.0		6.6		4.7
Nitrobenzene		4.0		<0-7		<0 7
Petrol ether 60-80		Misc		Misc		63
Petrol ether 80-100		40		63		41
Petrol ether 100-120		27		34		23
iso-Propyl alcohol	8.9	9.4	19	9.1	3.8	6.1
Silicone oil (550)		<0.7		<0.7		<0.7
Tetrachloroethylene		6.7		5.9		4.7
Toluene	2.9	4.8	7.1	5.3	3.8	4.6
Trichloroethylene		7.4		6.6		5.5
Transformer oil		3.3		3.7		<0.7
Xylene (m)	3.9	1.9	7.1	6.2	3.8	6.7