Microemulsions are thermodynamically stable, optically isotropic dispersions of aqueous and hydrocarbon liquids that are stabilized by an interfacial film of surfactant molecules.

Microemulsions are generally described as monodispersed spherical droplets (50–1000 Angstrons in diameter) of water in oil or oil in water depending upon the nature of the surfactants and the composition of the microemulsion.

The availability of high interfacial area, combined with thermodynamic stability, the ability to solubilize otherwise immiscible liquids, the low viscosity and the ultralow interfacial tension are some characteristic of microemulsions.

These properties have led to the use of microemulsions in cosmetics, pharmaceutics, lubrication, food technology, agricultural sprays, coatings, environmental remediation, cleaning, combustion, chemical synthesis, microporous media synthesis, and chemical analysis.

Application of microemulsions

- enhanced oil recovery
- soil remediation
- metal extraction
- detergency
- lubrication and cutting oils
- pharmacy and cosmetics
- medium for organic reactions
- medium for enzyme catalyzed reactions
- particle preparation

Microemulsion properties relevant for technical applications

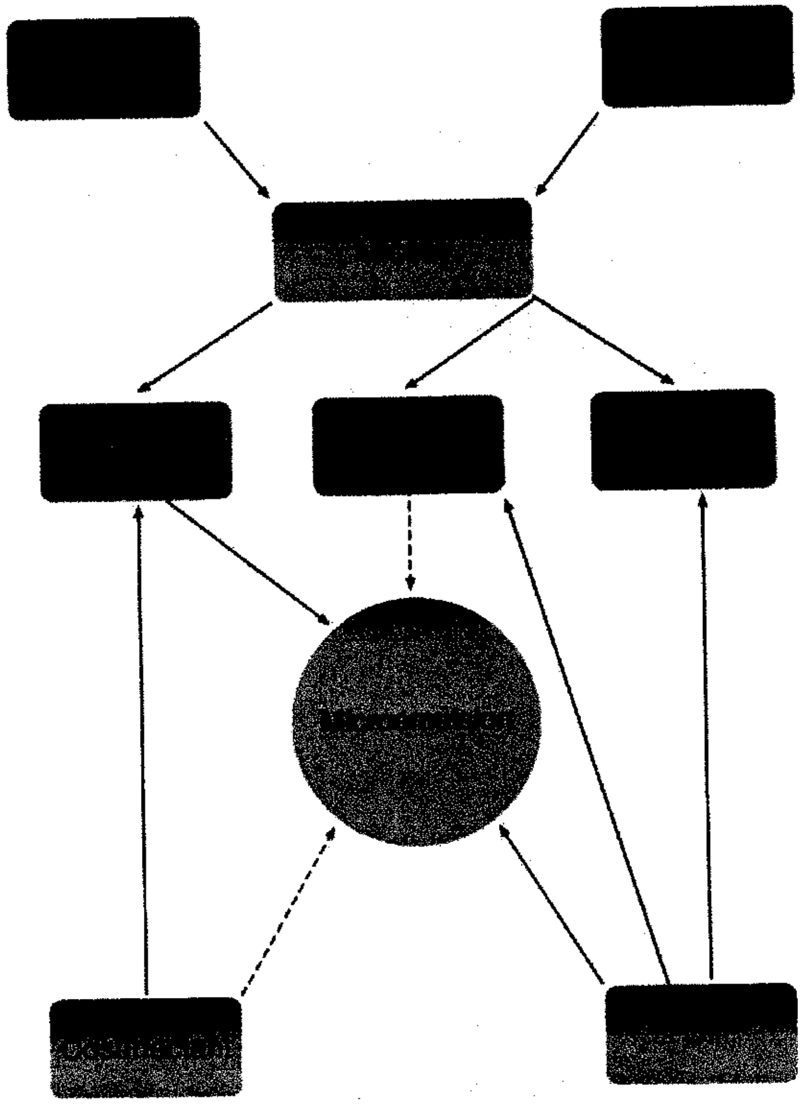
- thermodynamically stable system
- easy phase separation (T, pH)
- ultralow interfacial tension
- excellent wetting properties
- high solubilisation capacity
- fast solubilisation kinetics
- optical transparency
- low viscosity (compared to liquid crystals)
- large interfacial area
- nearly monodisperse particle distribution

Definition of Microemulsions

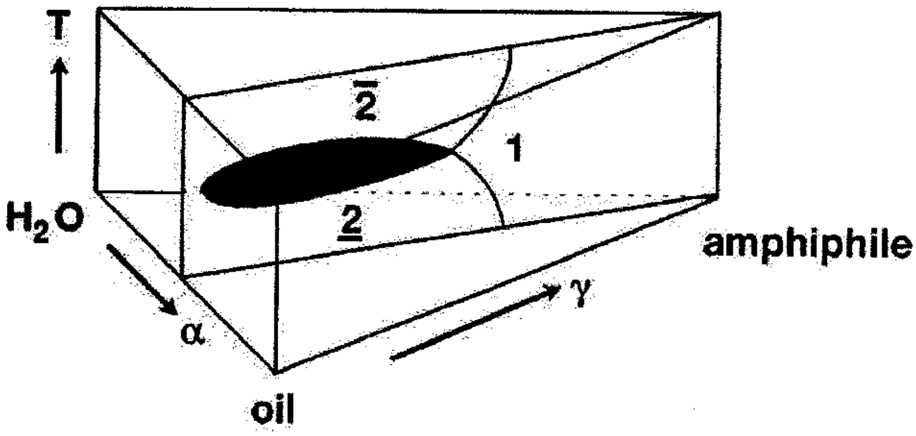
Optically Isotrope, Transparent and Thermodynamically Stable Mixtures of Water, Oil, Surfactant (and Cosurfactant)

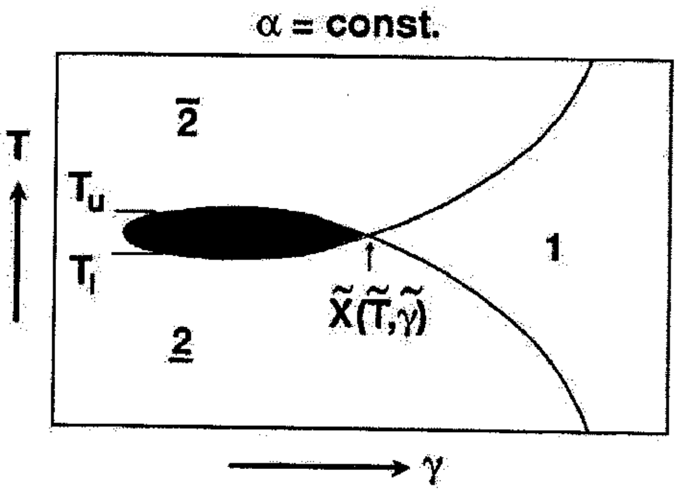
Isotrope : Optical Properties Independent of Direction of Light

Transparent : "Particle Size" $\leq \frac{\lambda}{4}$ (140nm)



Schematic phase prism





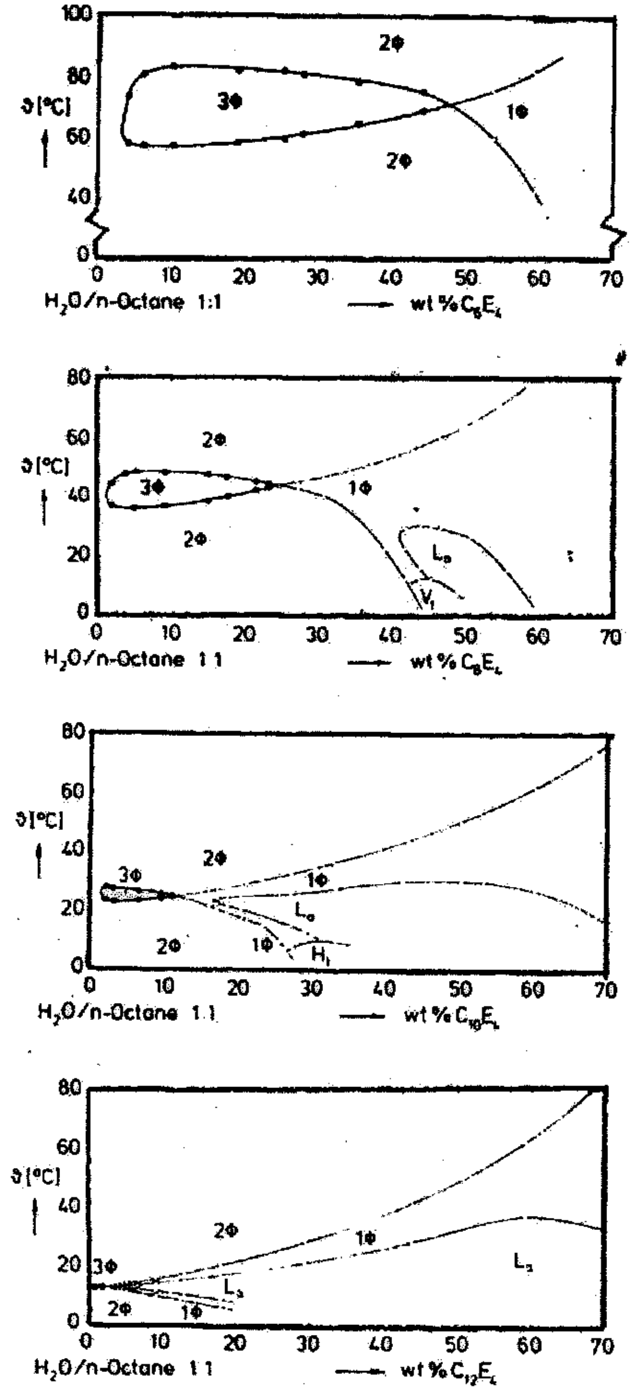


Figure 6. Vertical sections through the phase prism of the systems H_2O–*n*-octane–C_iE_4 (i = 6, 8, 10, 12).

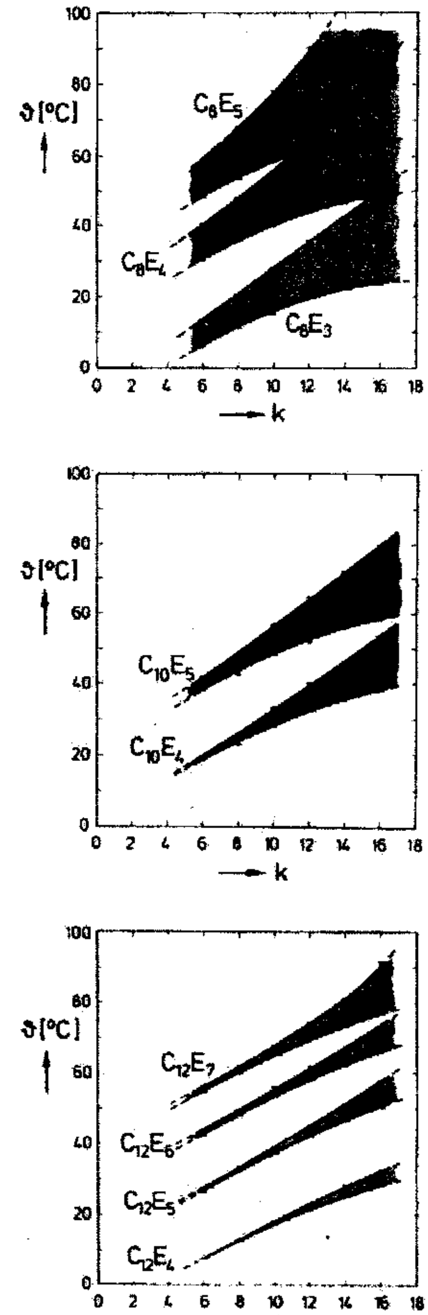
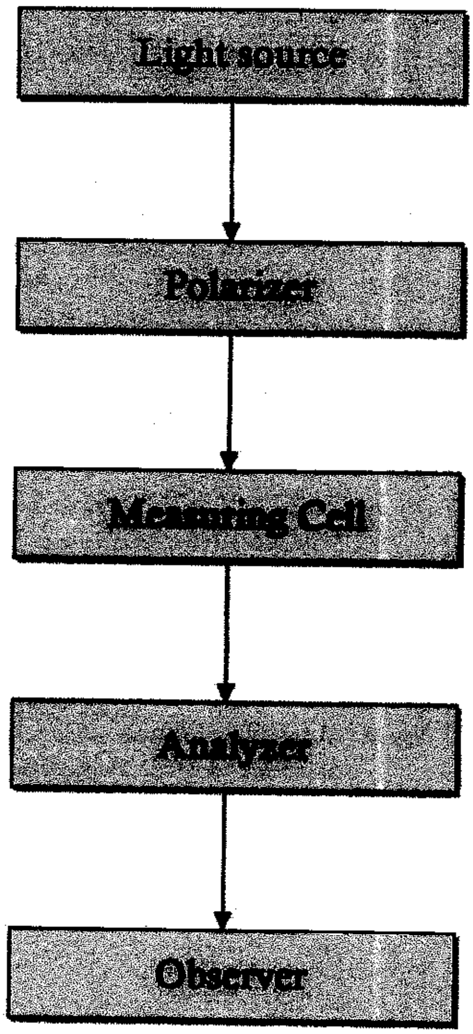
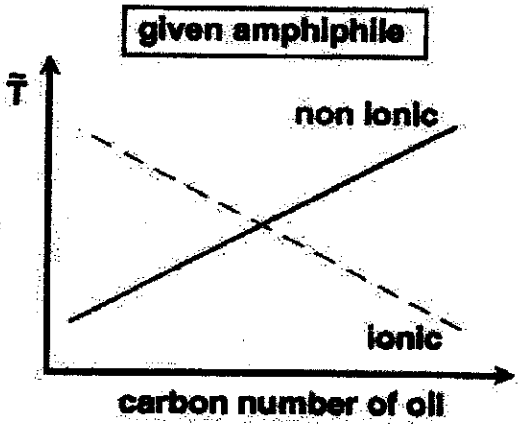


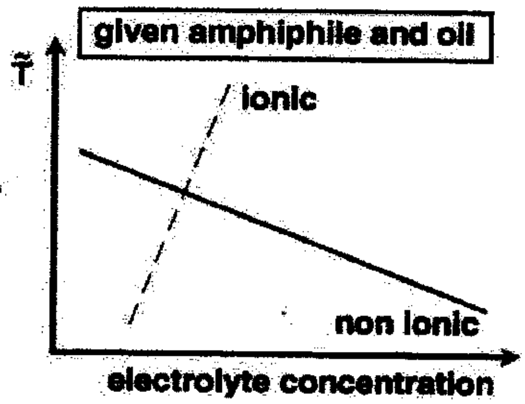
Figure 4. Three-phase temperature intervals ($T_u - T_l$) for H_2O–n-alkanes–C_iE_j (i = 4, 6, 8, 10, 12).



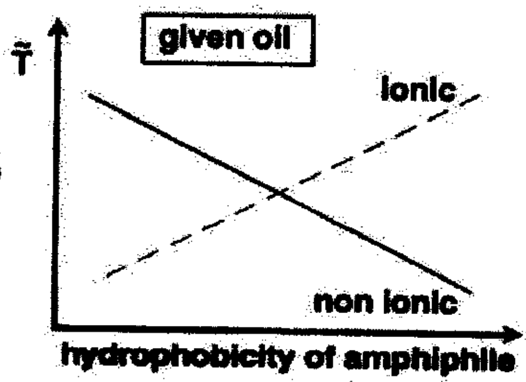
Schematic measuring order for detection of liquid crystals a)


given amphiphile
T̃
non ionic
ionic
carbon number of oil

b)


given amphiphile and oil
T̃
ionic
non ionic
electrolyte concentration

c)


given oil
T̃
ionic
non ionic
hydrophobicity of amphiphile

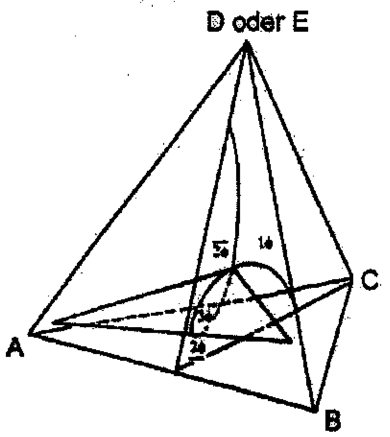


Abbildung 3.16: Das Phasenverhalten eines quaternären Systems bei fester Temperatur aus [72]

Es gibt vier Möglichkeiten, aus einem ternären Mikroemulsionssystem durch Zugabe einer vierten Komponente ein quaternäres System herzustellen. Diese vier Systeme und die sie charakterisierenden Mischungsverhältnisse sind in der folgenden Tabelle dargestellt:

System	Zum System A-B-C oder A-B-D hinzugegeben	charakterisierende Mischungsverhältnisse		
A-B-C-E	Elektrolyt E	$\alpha=\frac{B}{(A+E)+B}$	$\gamma=\frac{C}{(A+E)+B+C}$	$\varepsilon=\frac{E}{A+E}$
A-B-D-E	Elektrolyt E	$\alpha=\frac{B}{(A+E)+B}$	$\gamma=\frac{D}{(A+E)+B+D}$	$\varepsilon=\frac{E}{A+E}$
A-B-C_1-C_2	zweites nichtionisches Tensid C_2 oder Cotensid	$\alpha=\frac{B}{A+B}$	$\gamma=\frac{C_1+C_2}{A+B+C_1+C_2}$	$\delta=\frac{C_1}{C_1+C_2}$
A-B-C-D	ionisches Tensid	$\alpha=\frac{B}{A+B}$	$\gamma=\frac{C+D}{A+B+C+D}$	$\delta=\frac{D}{C+D}$

Tabelle 3.1: charakterisierende Mischungsverhältnisse für das quaternäre System

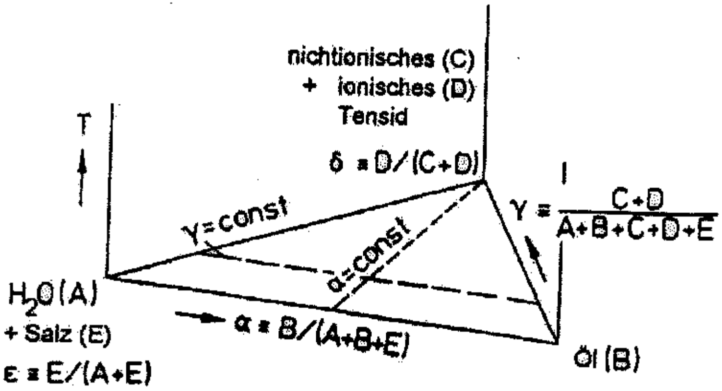


Abbildung 3.17: pseudoternäres Phasenprisma mit T als Ordinate und dem Dreieck (A + E) - B - (C + D) als Basis, mit konstantem δ und ε

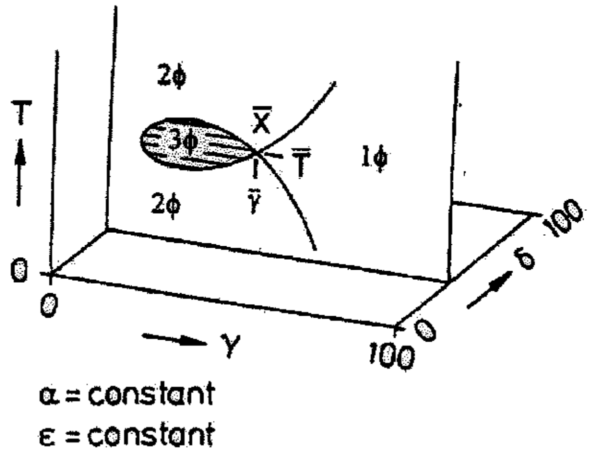


Abbildung 3.18: vertikale Schnitte durch das Prisma bei konstantem α, ε

Methods of soil remediation

- **In-situ decontamination (Methods requiring no excavation)**

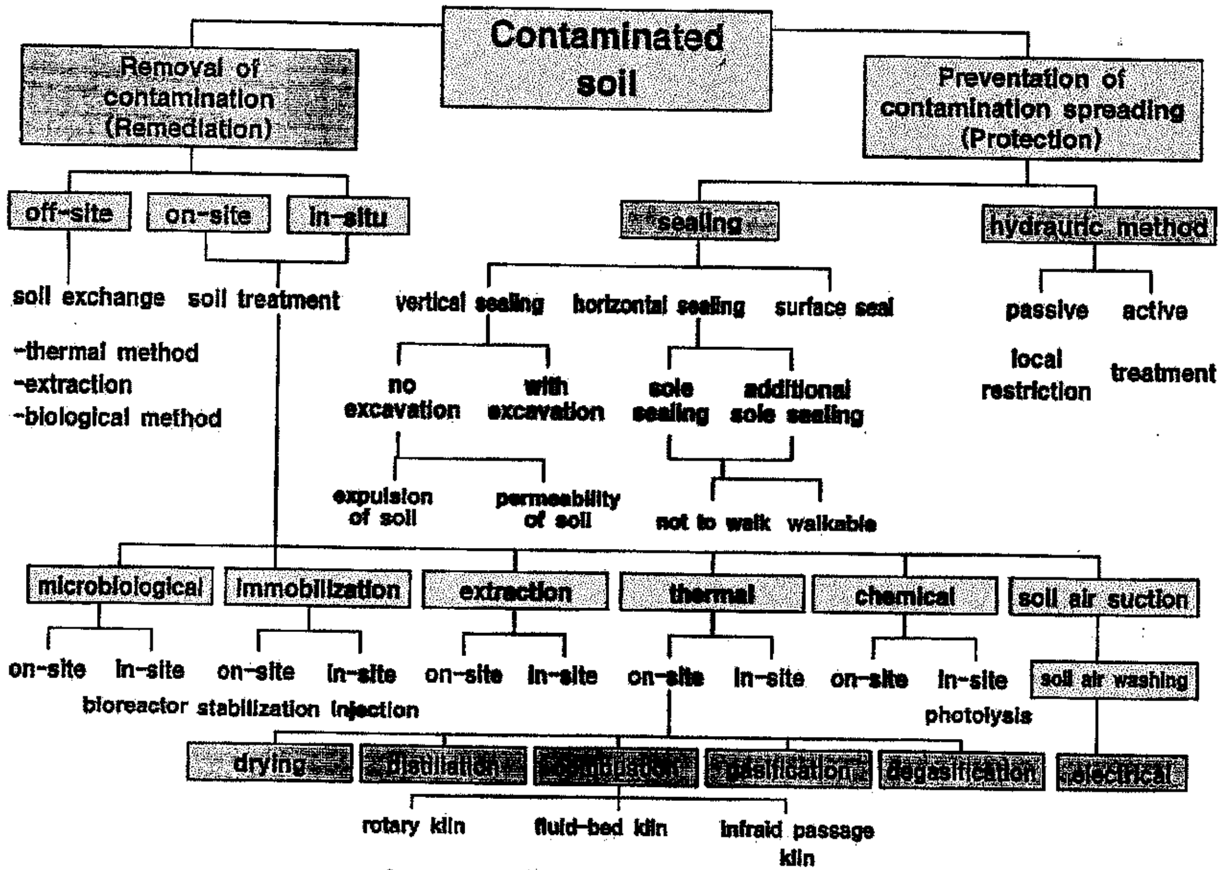
  Contamination are removed from the subsurface by extraction or trasformation

- **On-site technologies (Methods with excavation)**

  The excavated soil is treated at the contaminated site

- **Off-site technologies (Methods with excavation)**

  The excavated soil is transported to a treatment plant



Remediation of soil

표 5: 오염물질에 따른 처리기술

기술명 \ 오염물질		중금속	시안화합물	탄화수소, 광유	다환 방향족탄화수소	휘발성 염소화탄화수소	할로겐 유기화합물
토양공기흡입법(Bodenluftabsaugung)		X	X	X	X	0	X
열처리법 (Thermische Verfahren)	고온처리와 폐기가스소각법 (Hochtemperatur- u. Abgasverbrennung)	?	0	0	0	0	0
	저온처리와 폐기가스소각법 (Niedertemperatur- u. Abgasverbrennung)	X	0	0	?	0	X
추출 또는 세척법 (Extraktions-/Waschverfahren)		0	0	0	0	0	?
생물학적 방법 (Biologische Verfahren)		X	?	0	0	?	0

적합: 0
조건적 사용가능 또는 불규명: ?
부적합: X

표 6: 토양의 종류에 따른 처리기술

토양의 종류 / 기술명		입자가른 모래땅	비옥한 모래땅	점토질 땅	유기질 땅	불균일한 땅
토양공기흡입법(Bodenluftabsaugung)		0	0	X	?	?
열처리법 (Thermische Verfahren)	고온처리와 폐기가스소각법 (Hochtemperatur- u. Abgasverbrennung)	0	0	0	?	0
	저온처리와 폐기가스소각법 (Niedertemperatur- u. Abgasverbrennung)	0	0	0	?	0
추출 또는 세척법 (Extraktions-/Waschverfahren)		0	?	X	?	?
생물학적 방법 (Biologische Verfahren)		0	0	?	0	0

적합: 0
조건적 사용가능 또는 불규명: ?
부적합: X

표 8: 물리화학적 처리법의 개요

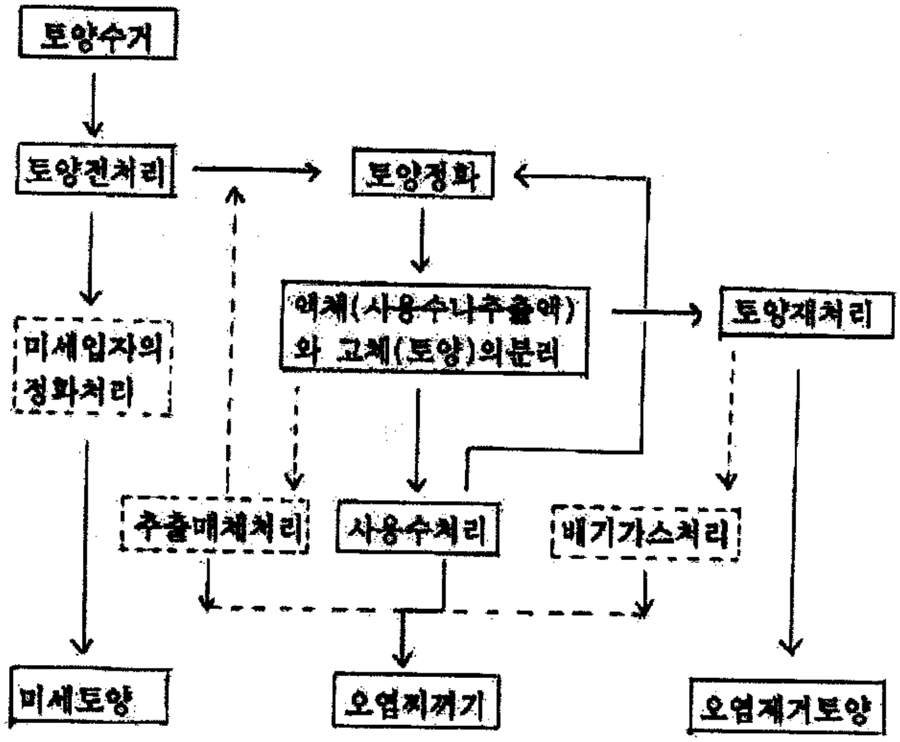
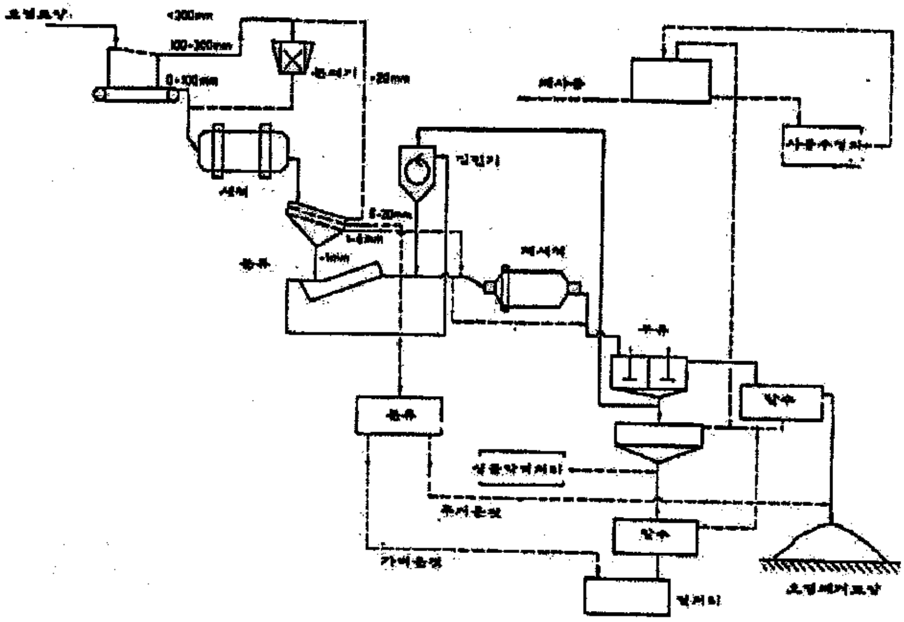
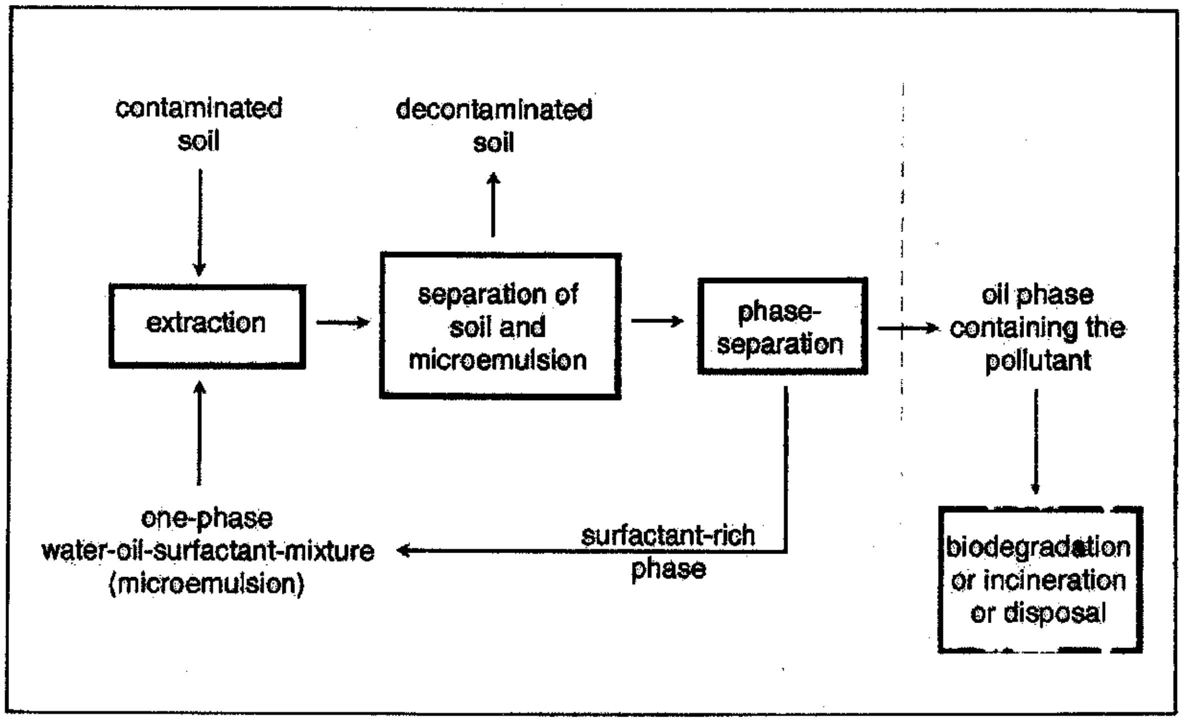


그림 4: 토양세척법



Concept for soil remediation applying microemulsions



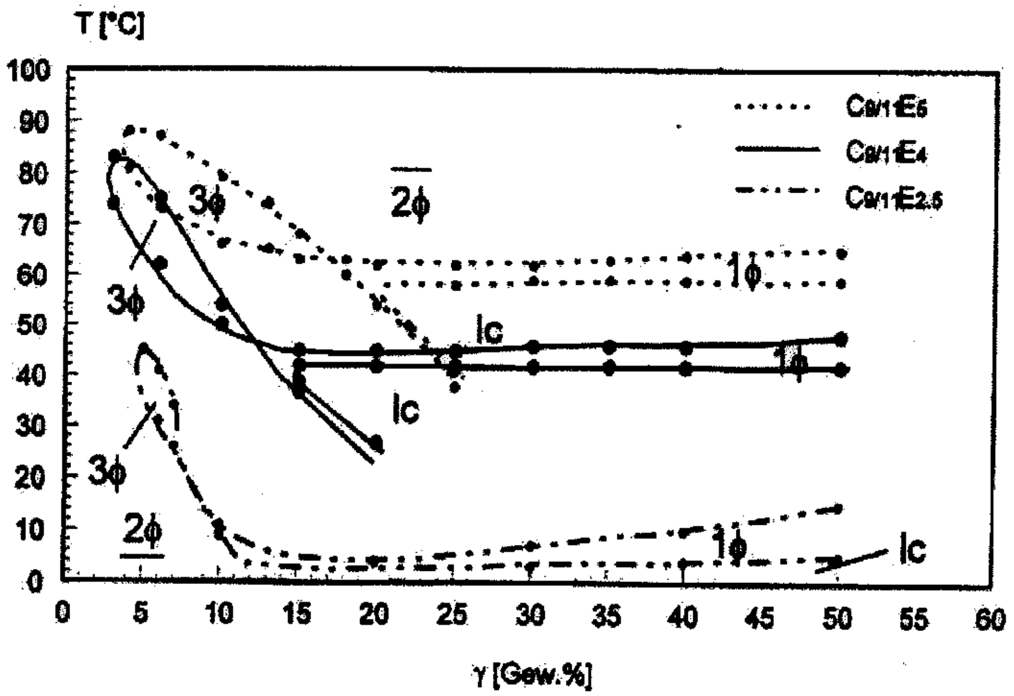


Abbildung 5.9: Phasendiagramm iso-Oktan - $C_{9/11}E_{2.5}$, iso-Oktan - $C_{9/11}E_4$ und iso-Oktan - $C_{9/11}E_5$ bei $\alpha = 50\%$

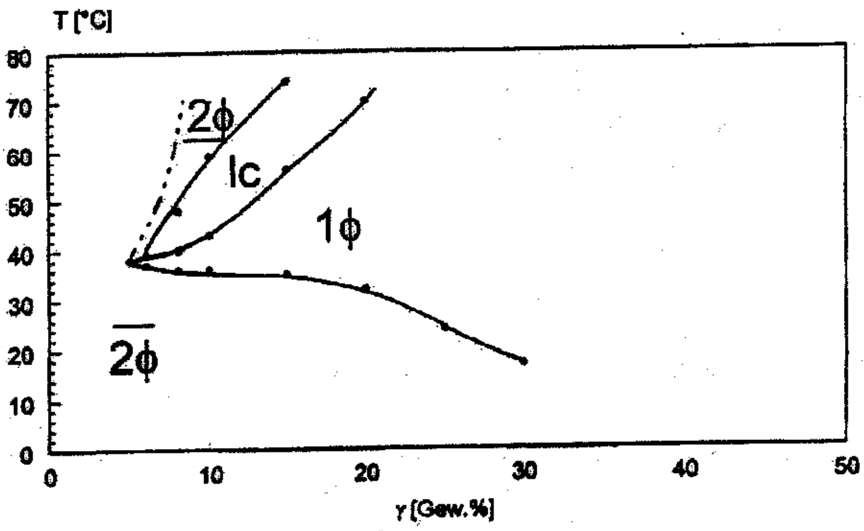


Abbildung 5.14: Phasendiagramm 0,25% NaCl - iso-Oktan - AOT
(α=50 Gew.%, ε=0,25 Gew.%)

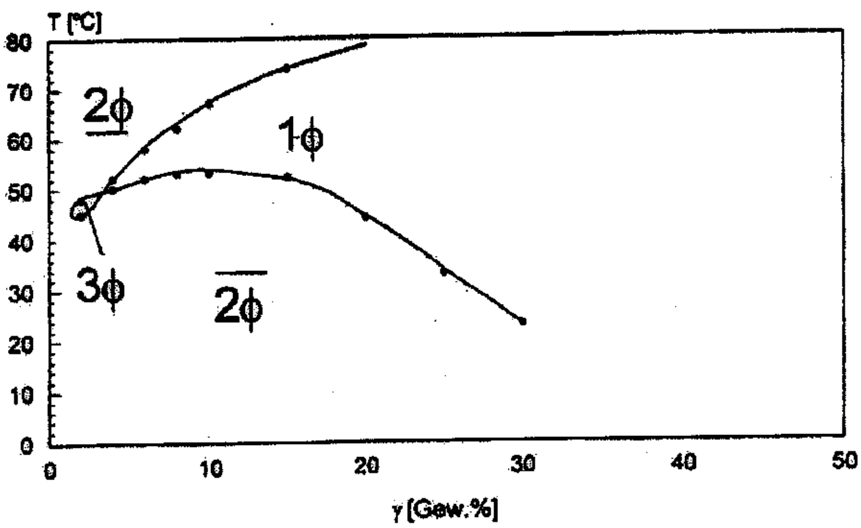


Abbildung 5.15: Phasendiagramm 0,5% NaCl - iso-Oktan - AOT
(α=50 Gew.%, ε=0,5 Gew.%)

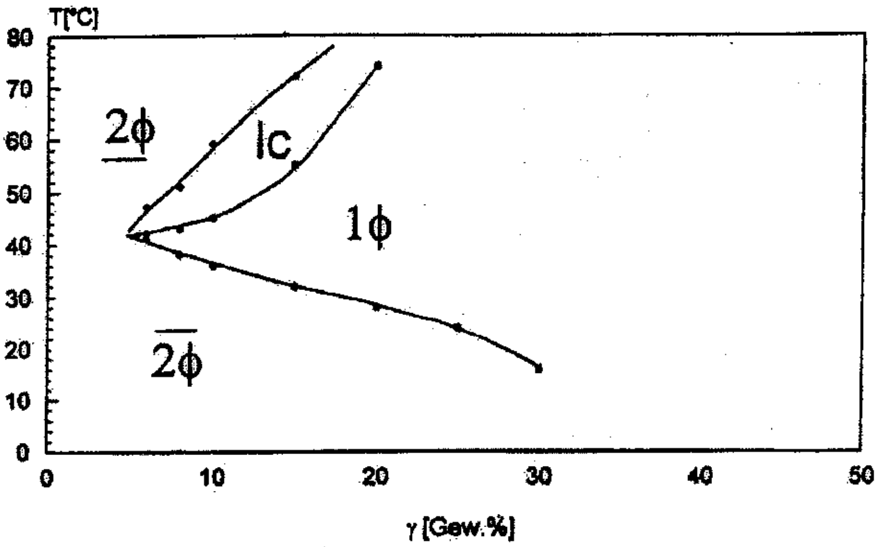


Abbildung 5.16: Phasendiagramm 0,25% $CaCl_2$ - iso-Oktan - AOT
(α=50 Gew.%, ε=0,25 Gew.%)

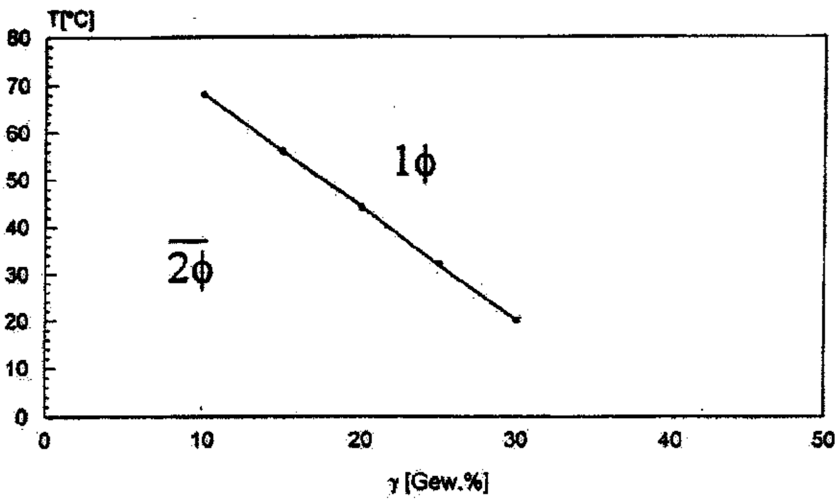


Abbildung 5.17: Phasendiagramm 0,5% $CaCl_2$ - iso-Oktan - AOT
(α=50 Gew.%, ε=0,5 Gew.%)

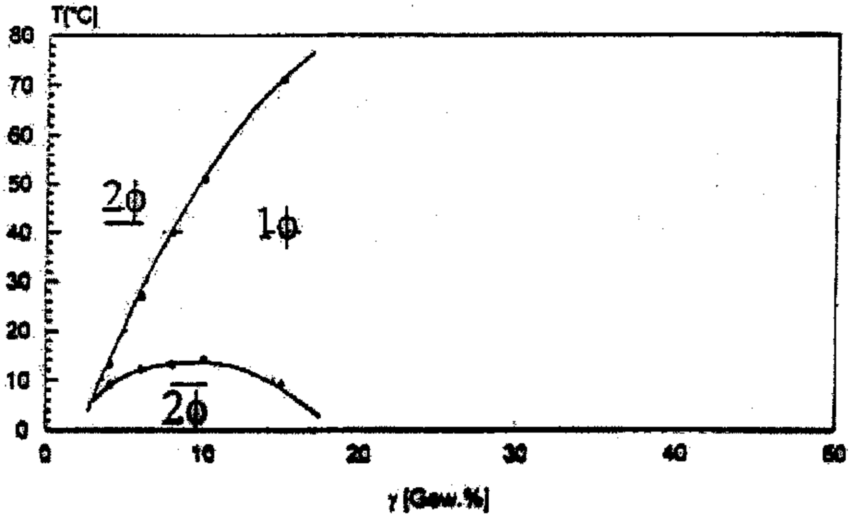


Abbildung 5.20: Phasendiagramm 0,5% NaCl - iso-Oktan – $C_{8/11}E_4$ - AOT
(α=50 Gew.%, ε=0,5 Gew.%, δ=70 Gew.%)

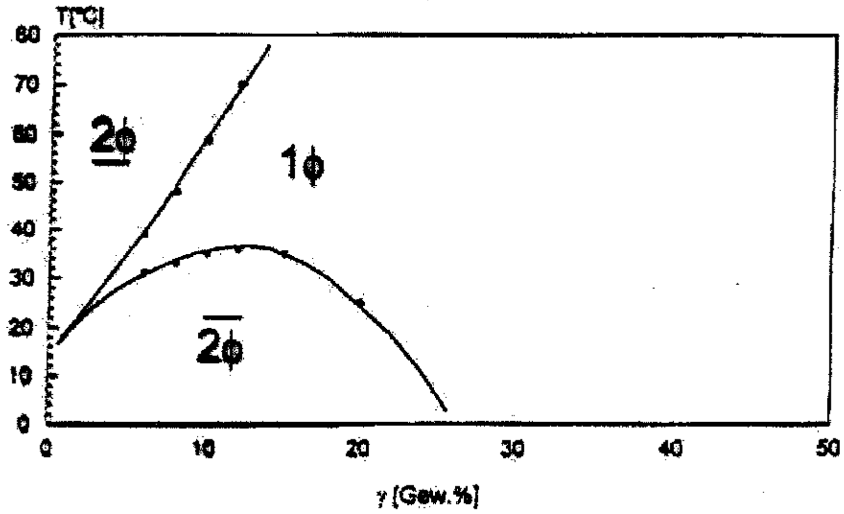


Abbildung 5.21: Phasendiagramm 0,5% NaCl - iso-Oktan – $C_{8/11}E_4$ - AOT
(α=50 Gew.%, ε=0,5 Gew.%, δ=80 Gew.%)

Parameter:

Lsg. (L) 50 g

Mikroemulsion: 10 g, 0.5% NaCl – iso-Oktan – AOT - $C_{8/11}E_4$ (7:3)

α = 50 %, γ = 15 %, ε =0,5 %

Pyren im Boden: 400 mg/kg

Temperaturen: 24 °C, 14°C

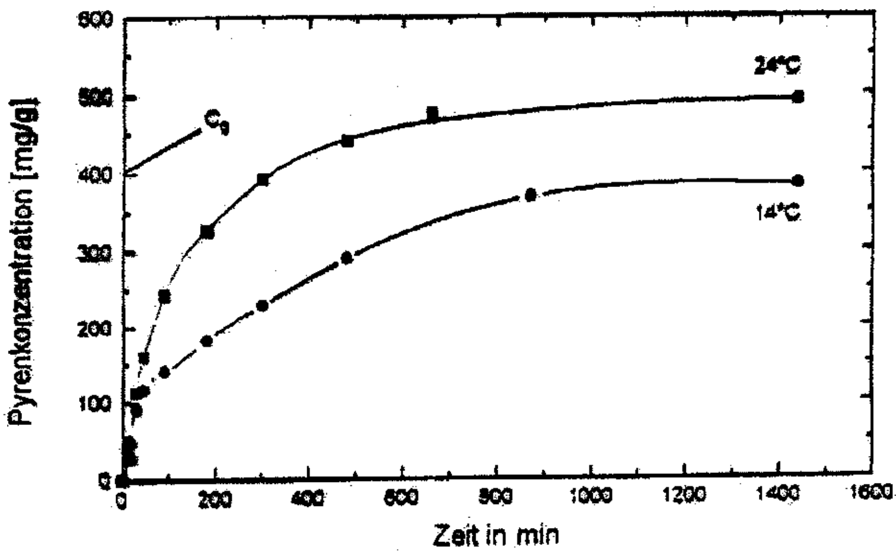


Abbildung 5.39: Extraktionskinetik des Systems 5 für die real kontaminierte Bodenprobe bei T = 14 °C und 24 °C

Lubrication and cutting oils

- solubilisation of corrosive agents → corrosion inhibition
- higher heat capacity than pure oils → cooling agent

Applications in pharmacy and cosmetics

Requests

- low allergenic potential
- good physiological compatibility
- high biocompatibility

These requests are fulfilled for example by AOT, lecithines, polysorbates

Applications in pharmacy and cosmetics

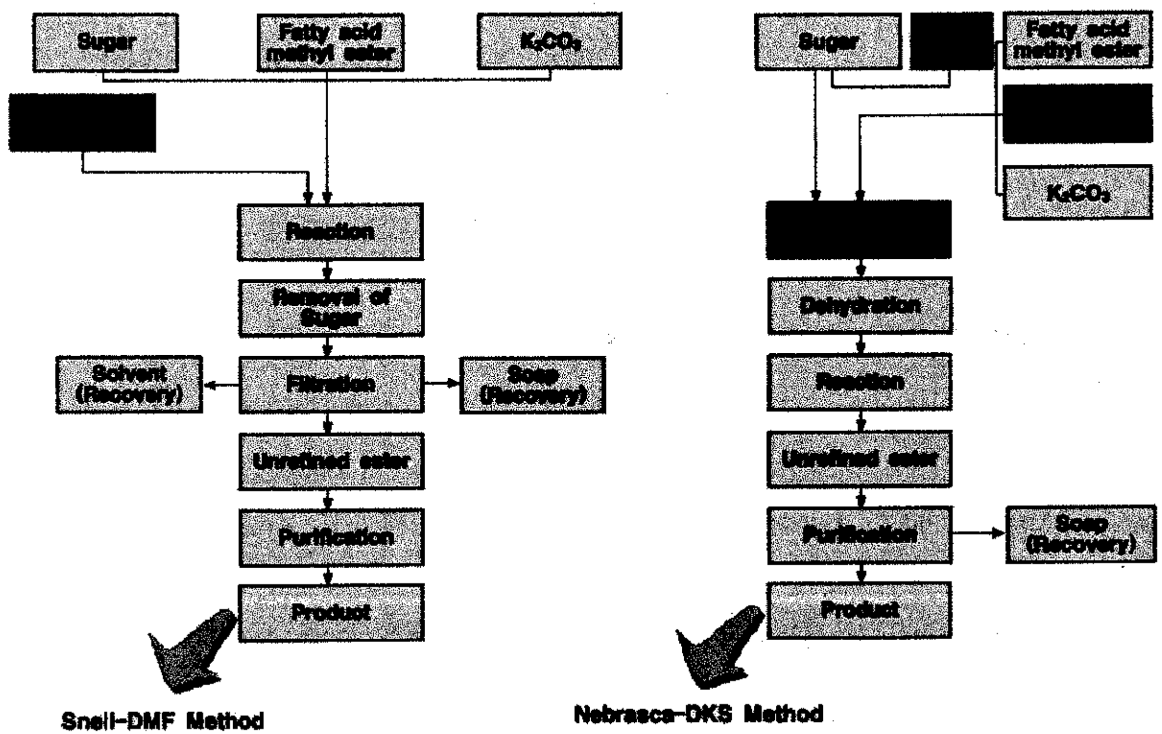
Advantages

- solubilisation of pharmaceuticals and cosmetics
- stabilisation of these components
- better storage (because of thermodynamic stability)
- cheap preparation of the formulation
- no immun reaction of the organism or fat embolism (because of the small droplet size)
- microemulsion formulations can be used as injectants
- higher diffusion rate of pharmaceuticals compared to usual formulations
- higher skin penetration flux
- no denaturation of proteins caused by protein-surfactant interactions

Potential applications for microemulsions

1. reaction medium for organic reactions

- hydrophobic and hydrophilic reactants can be dissolved in the same medium
- alternative to polluting solvents like DMSO, DMF, acetonitrile
- large internal interfaces → increase of the reaction rate
- good separation of products by phase separation
- influence on the equilibrium
- reaction progress can be traced by phase behaviour



Synthesis of Sugar ester

2. Reaction medium for enzyme catalysed reactions

- enzymes and substrates can be dissolved in the same medium
- enzymes do not loose their activity even at low water content of the microemulsion
- higher concentrations of the reactant can be achieved

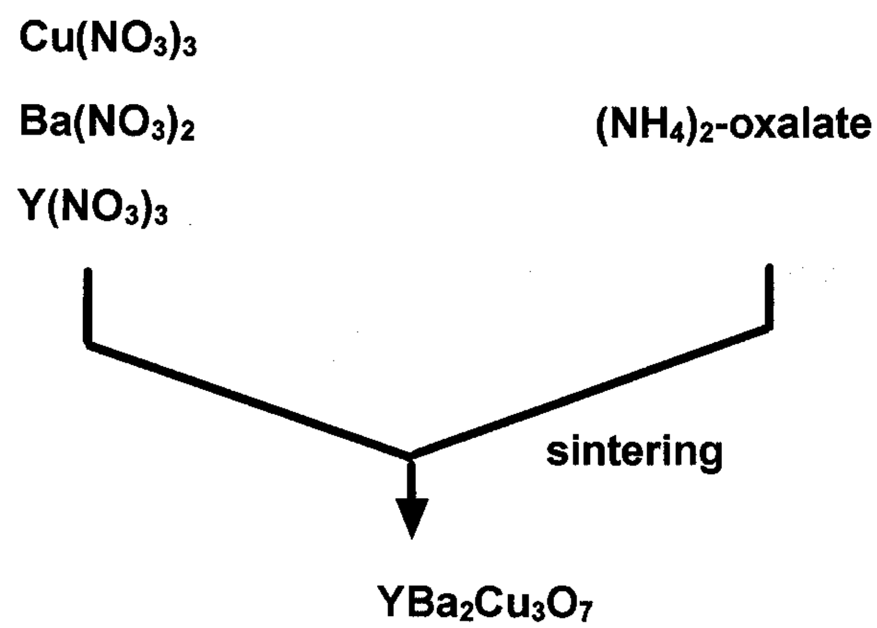
  → higher reaction rate

example : lipase catalysed esterification

3. Preparation of particles in microemulsions

- ultrafine particles
- small size distribution range, given by the size of the water domains
- relevant for e.g. catalysts, magnetic particles, superconductors, electrode material, semiconductors

Coprecipitation yielding superconductors



Formation of CdS-particles