Supercritical Fluid Technology: Extraction and Aerogels

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- Introduction to supercritical fluids
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- Supercritical wood impregnation
- Aerogels: properties and applications

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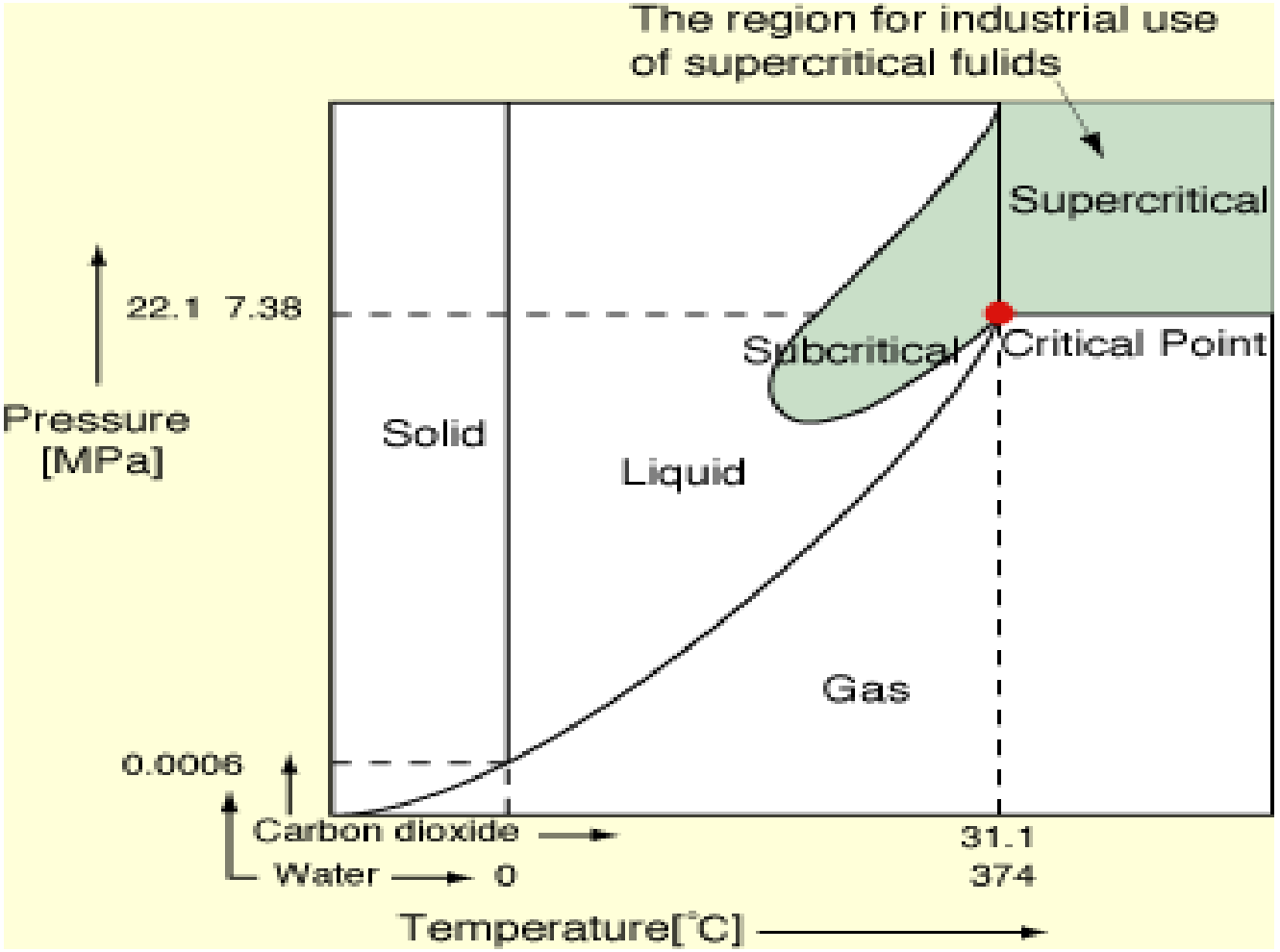
Supercritical phase



Properties of supercritical fluids

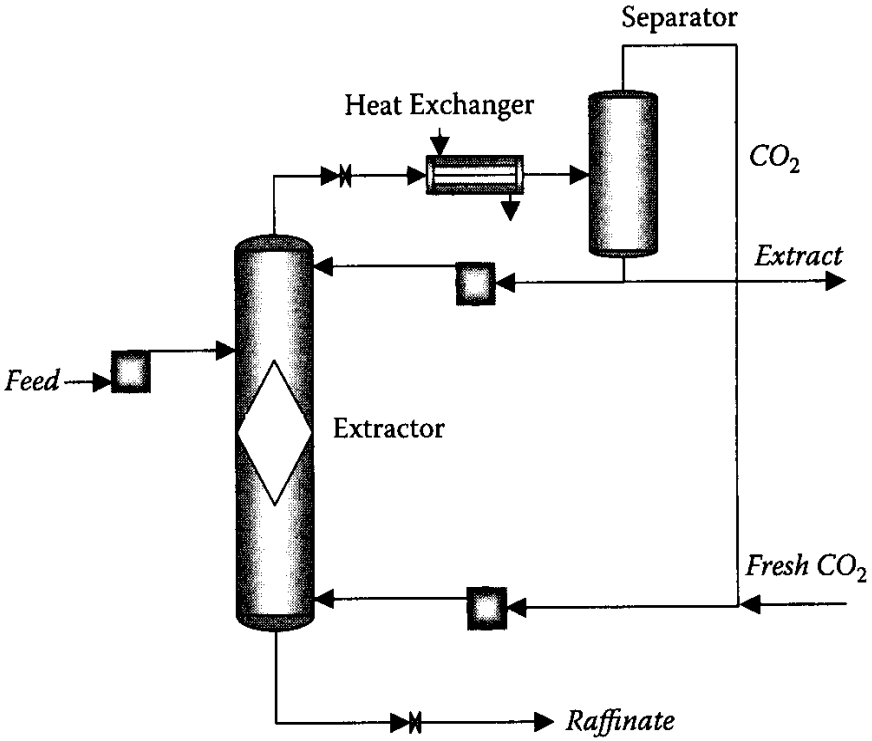
- Physicochemical properties of supercritical fluids (SCFs) are in between of those liquid and gas
  - Solubilities approaching liquid phase
  - Diffusivities approaching gas phase
  - Negligible surface tension
- SCFs have *density-dependent* solvating power, which can be tuned with temperature and pressure
- Supercritical CO_2 is cheap, abundant and safe substance with moderate critical constants (31.1 °C, 73.3 bar)
- Other fluids of interest for supercritical processes include water, ethane, propane and methanol

Supercritical extraction

- Supercritical CO_2 (SC-CO_2) has been widely studied for various extraction processes
- SC-CO_2 is non polar and is thus generally a good solvent for lipophilic organic compounds
- Supercritical CO_2 have a number of potential advantages over traditional solvents: non toxicity, low processing temperatures, and ease of separation of solvent from the product
- The density dependent solvent power of SCFs allows the separation of different extracts from the solvent by sequential depressurization

Supercritical extraction process

- Solid or liquid feed material can be used
- SC-CO_2 is used in
  - decaffeination
  - extraction of volatile plant based oils
  - extraction of various bioactive compounds
  - processing and purification of fish oils



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Supercritical wood impregnation

- The possibility of using SC-CO_2 as a carrier medium in wood impregnation has been studied for two decades
- Potential benefits of supercritical impregnation
  - It is possible to impregnate the wood to the core
  - It is possible to impregnate species with low permeability
  - It is possible to impregnate heartwood
  - Fairly even distribution of fungicides inside the wood
  - After impregnation, the wood is dry and can be used immediately
  - Clean technology
- CO_2 can dissolve various biocides, including tebuconazole, propioconazole, and IPBC

Supercritical wood impregnation

- Superwood from Denmark has had commercial supercritical impregnation plant running form 2002, with 60,000 m^3 annual capacity
- Main wood species is spruce, both heartwood and sapwood
- Total fungice content 0.28 kg/m^3
- No physical changes to the wood after impregnation (generally depends on species)

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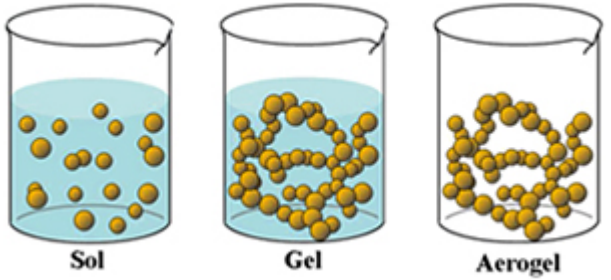
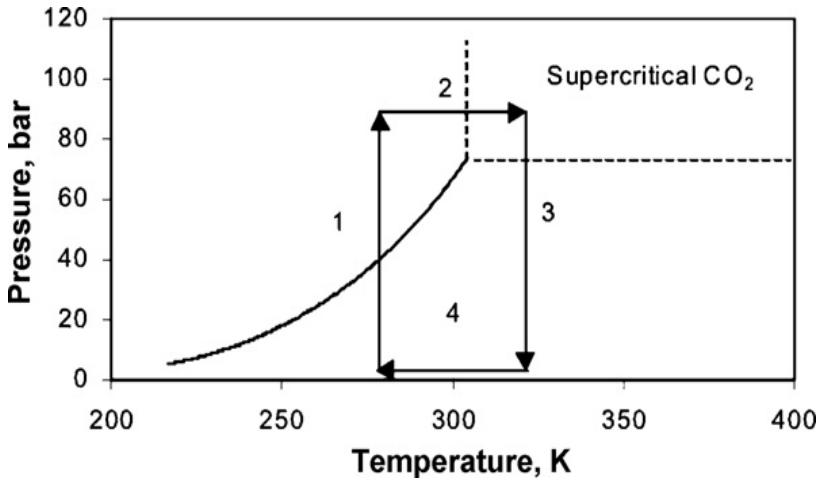
Aerogels

- Aerogels are derived from a gel where the liquid is replaced by a gas
- Silica aerogels are most the most common ones, prepared via sol-gel process
- Supercritical drying prevents the collapse of the gel structure during drying, because the liquid-gas interface is not crossed





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Aerogel properties

- Due to the highly porous and low density structure, aerogels have a number of special properties
  - Lowest thermal conductivity of any solid (5 - 15 mW/m-K)
  - Lowest density of any solid (0.003 - 0.15 g/cm^3)
  - High internal surface area (600 - 1000 m^2/g)
  - % Solids about 0.13 - 15
  - Low velocity of sound (~ 100 m/s)
  - Dielectric constant ~ 1.1

Silica aerogel tile insulating crayons from the heat of a blow torch

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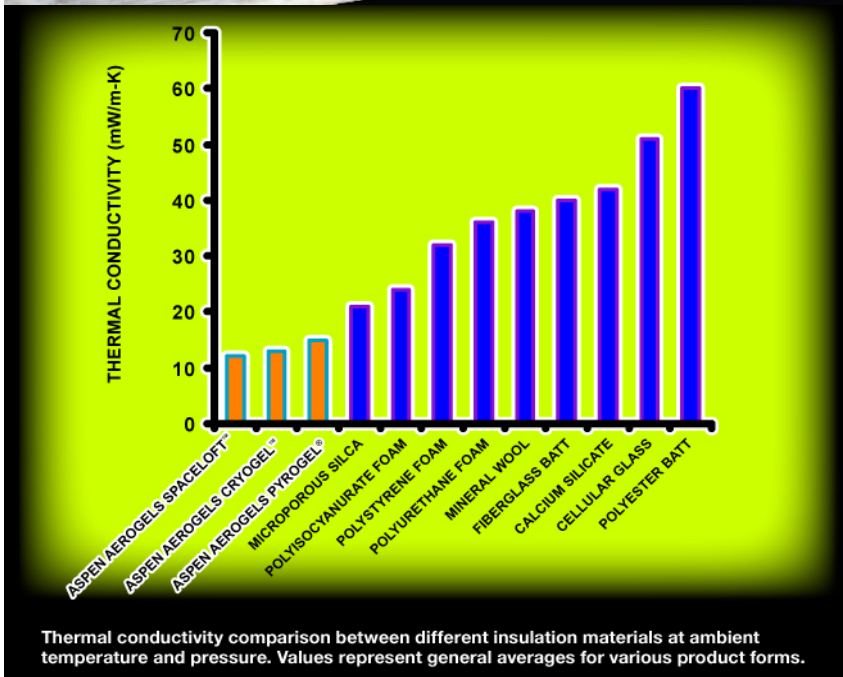
Aerogel applications

- Aspen Aerogels are producing silica aerogel based insulator sheets with reinforcing fibers
- Can be used in temperatures up to 600 °C
- Still somewhat expensive (49 - 79 €/m^2)



Thermal conductivity comparison between different insulation materials at ambient temperature and pressure. Values represent general averages for various product forms.

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Window glazings

- Airglass from Sweden is developing windows with evacuated aerogel sheet between double glass panels
- Thermal conductivity of about 21 mW/m-K for the whole structure
- For a 20 mm aerogel glazing, the center U - value is about 0.4 W/m^{2}K, which is comparable with rest of the thermal envelope of the building

Cellulose based aerogels

- New class of organic aerogels
- Monolithic aerogels were prepared from cellulose acetate and non-toxic isocyanate via sol-gel process, based on formation of urethane bonding by polycondensation reactions
- Dried with SC-CO_2 with considerable shrinkage
- Resulting material has density of 0.25 g/cm^3
- Effective thermal conductivity 29 mW/m-K, measured from granular bed of aerogel particles (0.1 - 3 mm)
- Already competitive with regular insulator materials

Summary

- Supercritical fluid tecnology has moved from lab-scale experiments into feasible industrial processes
- Equipment for supercritical processes are now more readily available
- SC-CO_2 is the most widely studied supercritical solvent, and it has proven useful in many extraction processes and in wood impregnation
- Large scale production of silica aerogels is quite well established
- Cellulose aerogels might offer interesting properties for future studies

Thank You!

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