Supercritical Fluid Extraction

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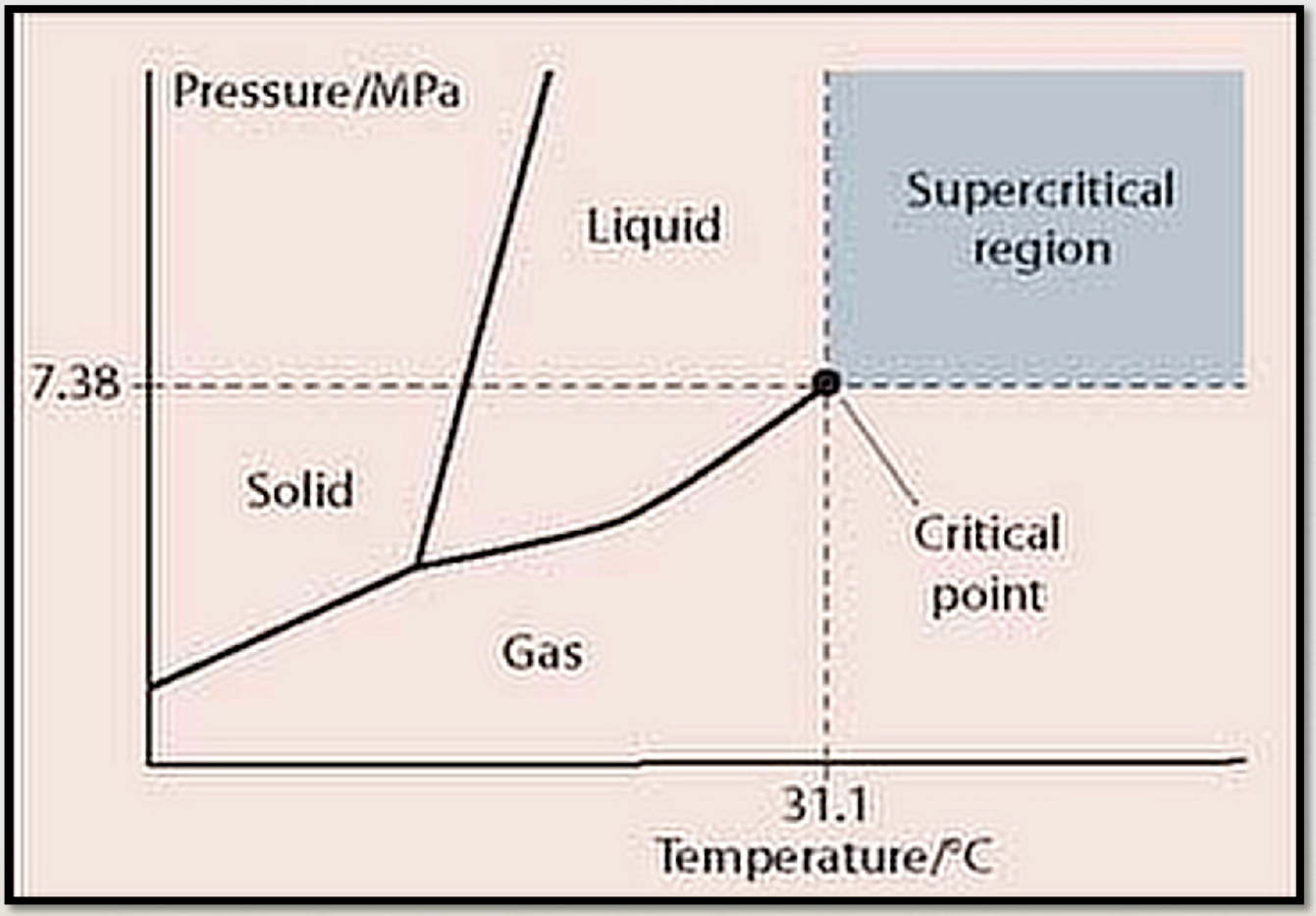
Supercritical Fluids



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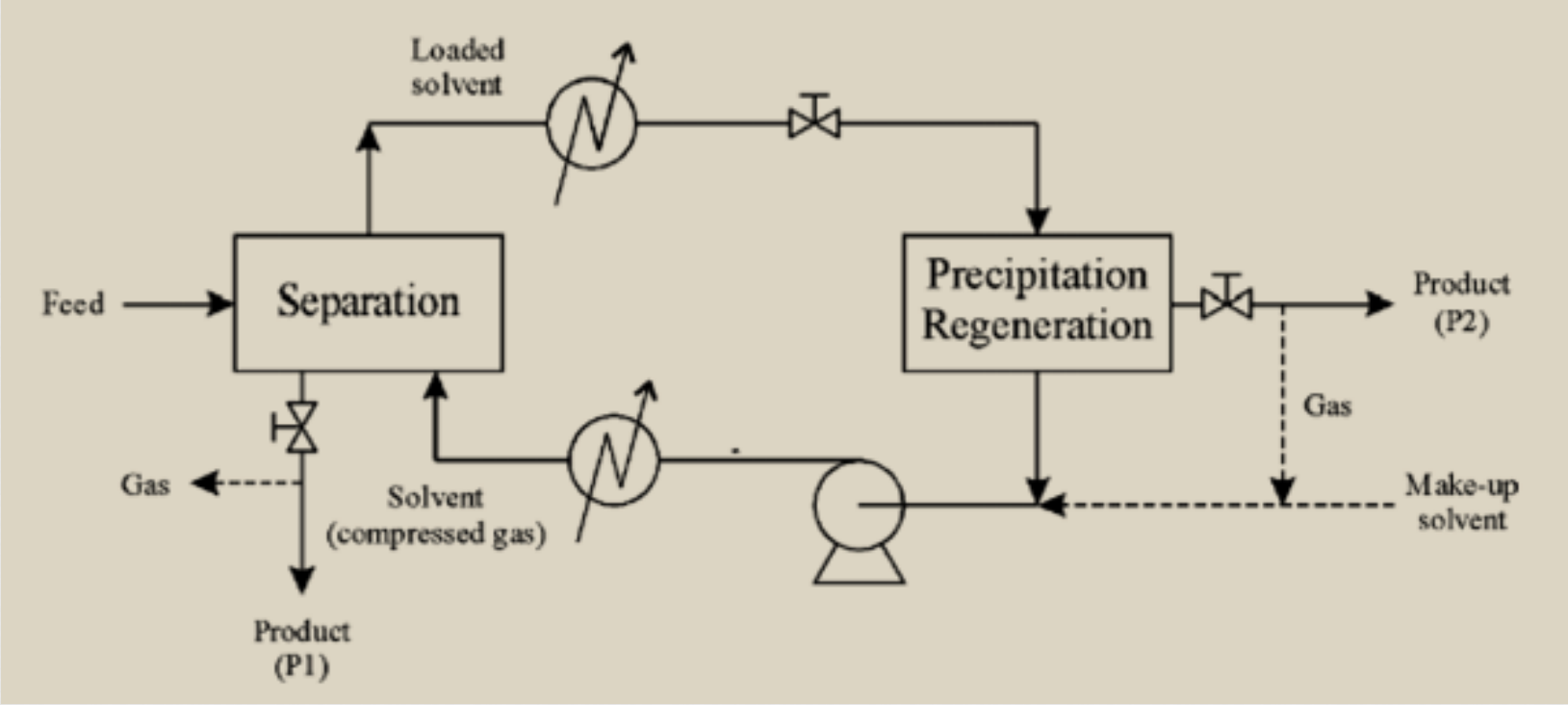
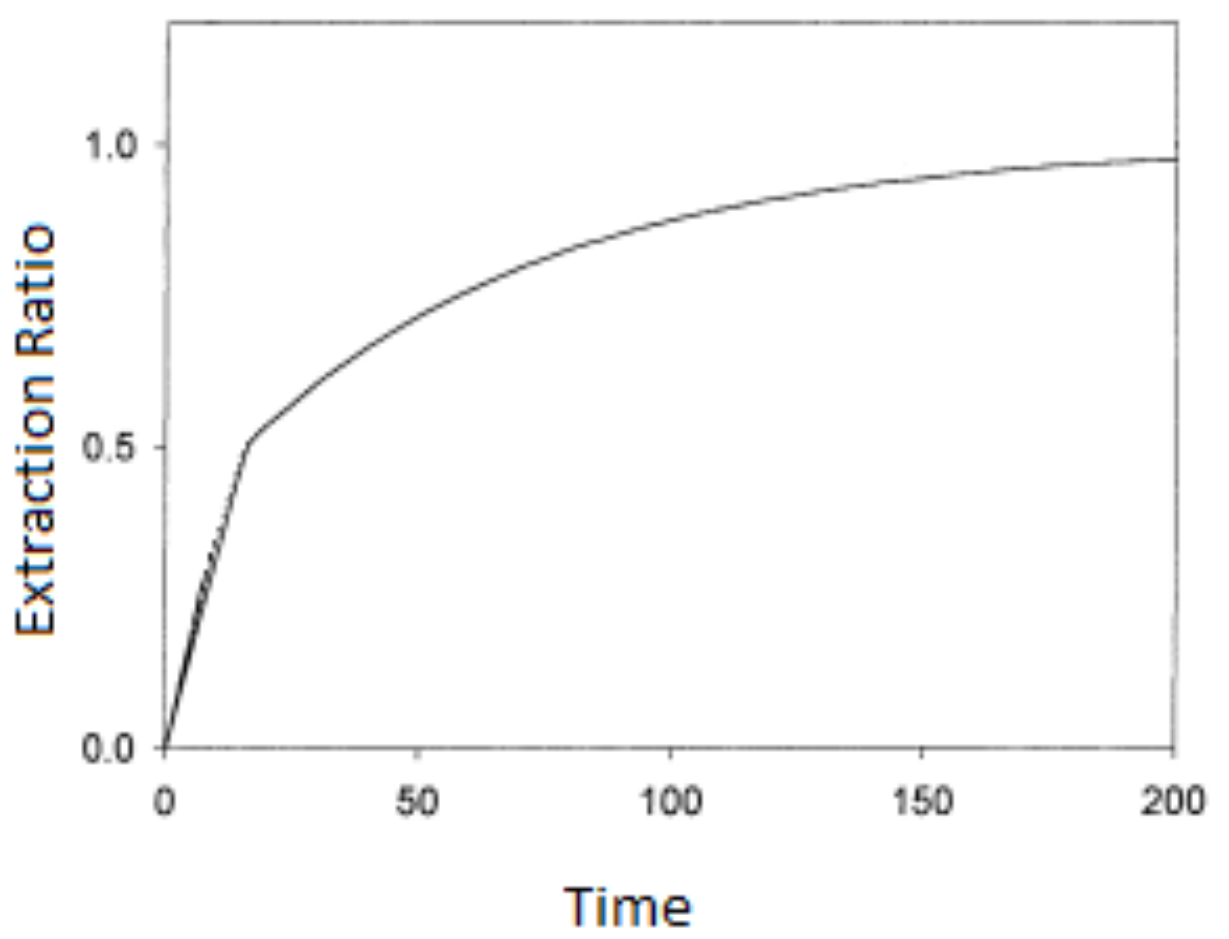


SCFE Performance



Decaffeination

- Coffee beans have many constituents giving it the rich and flavorful taste we all enjoy

What does decaffeination accomplish?

- Specific removal of caffeine without affecting the other constituents

Extractor Sizing

- Assuming coffee beans are spherical, with constant surface concentration:

$$\frac{m_t}{m_o} = 1 - B * \exp(-kt)$$

$$where \quad B = \frac{6}{\pi^2} \quad and \quad k = \frac{D\pi^2}{r^2}$$

Diffusivity (D) = $2x10^{-11}$ to $20\ x10^{-11}$ m^2/s

%Extracted (m_t/m_o) > 0.97

Radius ~= 0.32 cm

Extractor Sizing

- Total volume determined from mass of coffee beans in each batch:

$$V = M_{beans}/\rho_{beans} + \left[\frac{M_{beans}C_{caff}}{Sol_{caff/CO_2}} * \frac{M_{w,CO_2}}{M_{w,caff}}\right]/\rho_{CO_2}$$

Solubility: 0.025 moles caffeine / moles CO_2 @ 34°C & 10 MPa
Density of SC-CO_2: 660.2 kg / m^3
Density of coffee beans ~= 560 – 700 kg/m^3

Cost of SCFE

- A supercritical fluid extractor can be approximated by a pressurized vessel with one set of pumps
- Don Woods provides costing options for both:

Capital costs:

SCFE: $113,700 ± $45,500

Pumps: $66,000 ± $20,000

Total: $179,700 ± $65,500

Operating costs:

CO_2 Pressurization: $50, 700 annually

References

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- D.R. Woods, “Cost Estimations for the Process Industries”, McMaster University. Hamilton, ON. 1983
- Anderson, A., Shimoni, E., Liardon, R., Labuza, T.P., “The diffusion kinetics of carbon dioxide in fresh roasted and ground coffee,” Journal of Food Engineering, vol 59, pp. 71-78, 2003.