Determine Q, W, ΔU, ΔH, and ΔS for a hot compressed water (HCW) biomass pretreatment process

【Associated Sections in Selected Textbooks】

- *Introduction to Chemical Engineering Thermodynamics* [1] Sec. 6.1

【Module Learning Objectives】

- Calculation of enthalpy, internal energy, entropy and other thermodynamic property values from PVT and heat-capacity data.

【Problem】

Biomass is a complex mixture of natural polymers and refers to the biological material derived from living organisms and is the world's fourth largest energy source worldwide. There is a growing interest in using lignocellulosic biomass as renewable resource for biofuels production due to its high availability, since 10-50 billion tons are produced each year globally. The main components of biomass are lignin, cellulose and hemicelluloses. The celluloses are converted to fermentable monosaccharides for biofuel usage. The challenge lies in the mentioned components of lignocellulosic biomass being difficult to separate and dissolve in water at normal pressures and temperatures. Hot compressed water (HCW) is among several cost-effective pretreatment processes of lignocellulosic biomass for enzymatic hydrolysis.

HCW is defined broadly as liquid water above 473K and pressure between 10-20 MPa. It is cheap, highly available, non-flammable, and non-explosive. At high temperatures waters exhibits dramatic changes in physical properties, namely a lower dielectric constant, a lower coefficient viscosity, fewer hydrogen bonds and a higher capacity for dissolved organic matter which make it a good choice as a solvent [2].

In one pretreatment of rice straw by HCW process, one kilogram of water (V_1 = 1,003 cm^3kg^{-1}) at 25°C and 1 bar is compressed to 150 bar. Determine Q, W, ΔU, ΔH, and ΔS given that $\beta = 250 \times 10^{-6}\ K^{-1}$ and $\kappa = 45 \times 10^{-6}\ bar^{-1}$. The process can be assumed mechanically reversible and isothermal. In addition, V can be assumed constant at its arithmetic average value.

Bibliography

[1] J. Smith, H. Van Ness and M. Abbott, Introduction to Chemical Engineering Thermodynamics, 7th Ed. ed., New York: McGraw Hill, 2005.

[2] A. Rodrigues, P. Simoes, A. Fonseca, S. Barreiros and A. Paiva, "Paper Mill Sludge Hydrolysis Using Hot Compressed Water For Biodiesel Production By Oleaginous Yeast".