Exercise 9-1

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$$dU = TdS - PdV + \mu dn$$

a) U is a homogeneous function (multiplying all arguments of U is the same as multiplying U by the same number)

Then, by Euler's theorem:

$$U = S\left(\frac{\partial U}{\partial S}\right)_{V,n} + V\left(\frac{\partial U}{\partial V}\right)_{S,n} + n\left(\frac{\partial U}{\partial n}\right)_{S,V}$$

$$= ST - VP + n\mu$$

$$= TS - PV + \mu n$$

$$G = U - TS + VP$$

$$dU = TdS - PdV + \mu dn$$

$$dG = TdS - PdV + \mu dn - TdS - SdT + VdP + PdV$$

$$= \mu dn - SdT + VdP$$

$$\Downarrow$$

$$(dG)_{T,P} = \mu dn$$

$$\left(\frac{\partial G}{\partial n}\right)_{T,P} = \mu$$

$$F = U - TS$$

$$dF = TdS - PdV + \mu dn - TdS - SdT$$

$$= \mu dn - PdV - SdT$$

$$(dF)_{V,T} = \mu dn$$

$$\mu = \left(\frac{\partial F}{\partial n}\right)_{T,V}$$