Step 4: In what way can $\left(\frac{\partial g}{\partial v}\right)_P^{-1}$ be rewritten?

$$\left(\frac{\partial g}{\partial v}\right)_P^{-1} = \left[\left(\frac{\partial g}{\partial T}\right)_P \left(\frac{\partial T}{\partial v}\right)_P + \left(\frac{\partial g}{\partial P}\right)_T \left(\frac{\partial P}{\partial v}\right)_P\right]^{-1} = \left[-s\left(\frac{\partial v}{\partial T}\right)_P^{-1}\right]^{-1} = -\frac{v\beta}{s}$$