**Chemical Engineering Thermodynamics**
**Quiz 9**
**March 9, 2017**

1) Given the following equation of state **give expressions for the enthalpy and entropy departure functions**.

$$\frac{PV}{RT}=1+\frac{P}{RT}\left(b-\frac{a}{T}\right) \qquad \frac{H-H^{ig}}{RT}=-\int_0^P T\left(\frac{\partial Z}{\partial T}\right)_P\frac{dP}{P} \qquad \frac{S-S^{ig}}{R}=-\int_0^P\left[\left((Z-1)+T\left(\frac{\partial Z}{\partial T}\right)_P\right)\right]\frac{dP}{P}$$

2) Ammonia is used in an industrial refrigeration cycle. Rather than a throttle, an expander is used to produce recoverable work in the gas expansion step. The gas vapor is initially at 230°C (503°K) and 8 MPa, the ammonia exits the expander at 1 MPa. If the expander has an efficiency of 85%,

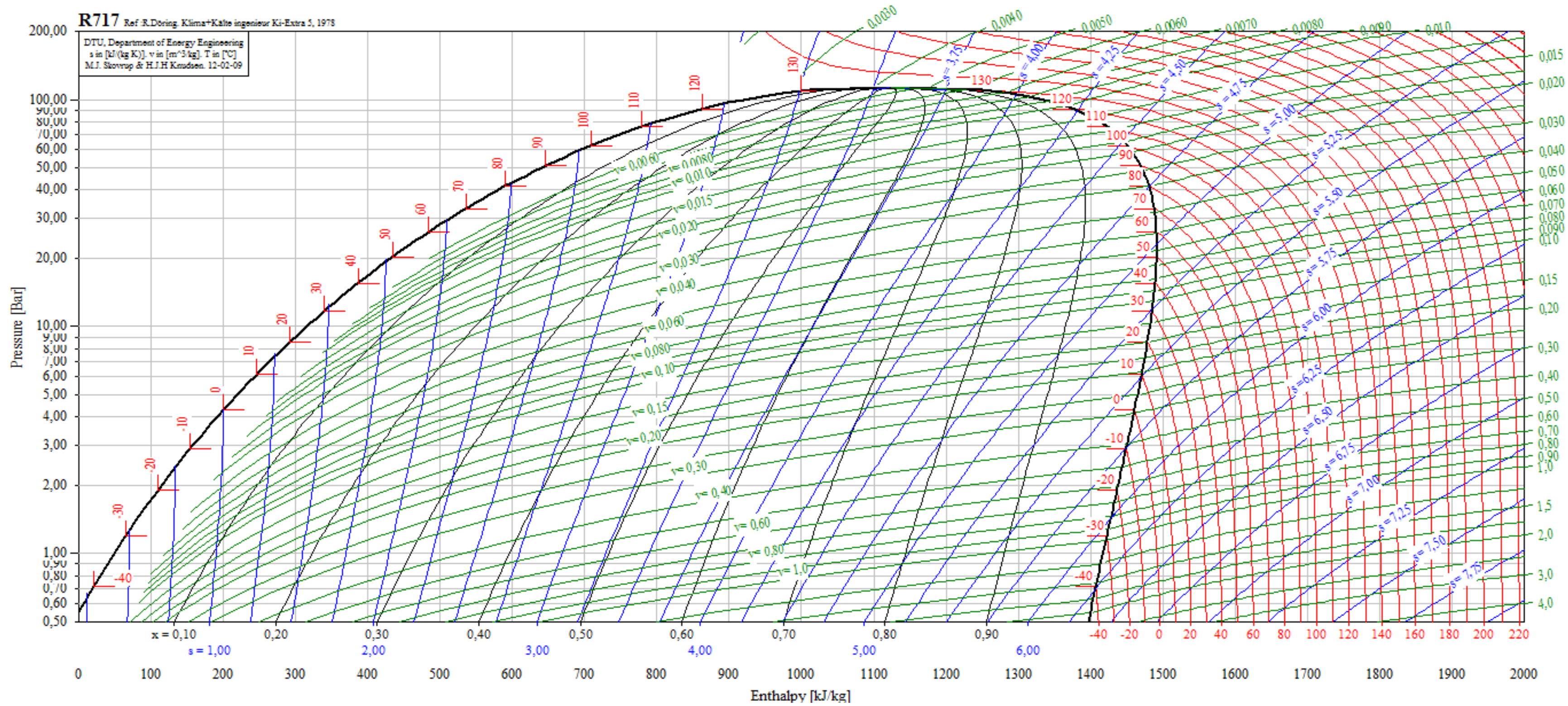
**-How much work is obtained per mole of ammonia**? (List the PREOS.xls setup and solver steps)

**-What is the final temperature of the ammonia**? (List the solver steps)

**-What is the temperature for a reversible expander**?

**-What is the temperature for a saturated vapor at 1 MPa?** (List the solver steps)

**-Show the four points, saturated vapor 1 MPa; reversible expander; 85% efficiency expander; and the initial condition on the following pressure-enthalpy chart for ammonia (Refrigerant 717).**



R717 Ref :R.Döring. Klima+Kälte ingenieur Ki-Extra 5, 1978
DTU, Department of Energy Engineering
s in [kJ/(kg K)], v in [m^3/kg], T in [°C]
M.J. Skovrup & H.J.H Knudsen. 12-02-09
Pressure [Bar]
Enthalpy [kJ/kg]

# Quiz 9
March 9, 2017
ANSWERS

1) $$\frac{H-H^{ig}}{RT} = -\int_0^P T\left(\frac{\partial Z}{\partial T}\right)_P \frac{dP}{P}$$

$$Z = 1 + \frac{P}{RT}\left(b - \frac{a}{T}\right)$$

$$\left(\frac{\partial Z}{\partial T}\right)_P = \frac{P}{R}\left(-\frac{b}{T^2} + \frac{2a}{T^3}\right)$$

$$\frac{H-H^{ig}}{RT} = \int_0^P \left(\frac{b}{RT} - \frac{2a}{RT^2}\right) dP$$

$$\frac{H-H^{ig}}{RT} = \frac{bP}{RT} + \frac{-2aP}{RT^2}$$

$$\boxed{H-H^{ig} = bP - \frac{2aP}{T}}$$

$$\frac{S-S^{ig}}{R} = -\int_0^P \left[(Z-1) + T\left(\frac{\partial Z}{\partial T}\right)_P\right]\frac{dP}{P}$$

$$= \int_0^P \left[\left(\frac{a}{RT^2} - \frac{b}{RT}\right) + \frac{1}{R}\left(\frac{b}{T} - \frac{2a}{T^2}\right)\right] dP$$

$$= \frac{aP}{RT^2} - \frac{bP}{RT} + \frac{bP}{RT} - \frac{2aP}{RT^2}$$

$$S-S^{ig} = \frac{P}{T}\left(\frac{a}{T} - \frac{2a}{T}\right)$$

$$\boxed{S-S^{ig} = -\frac{Pa}{T^2}}$$

2) - Duplicate Props as Props(2)

- Set Critical Props & Cp values to Ammonia

- Props set T to 503°K, P to 8 MPa — Set Ref State to 503°K 8 MPa

Props(2) set P to 1 MPa

- Set cell ΔS

= K9 + L4 − Props!K12

Add a Cell ΔH

= I9 + J4 − Props!I12

(use vapor phase result for Props (2))

- Solve cell ΔS' = 0 by varying TK

$T_2' = 307°K$

$\Delta H' = -6120$ J/mole

$\Delta H = W_s = \Delta H' \cdot 0.85 = -5200$ J/mole

- Solve cell ΔH to reach −5200 J/mol, vary TK

$T_2 = 330°K$

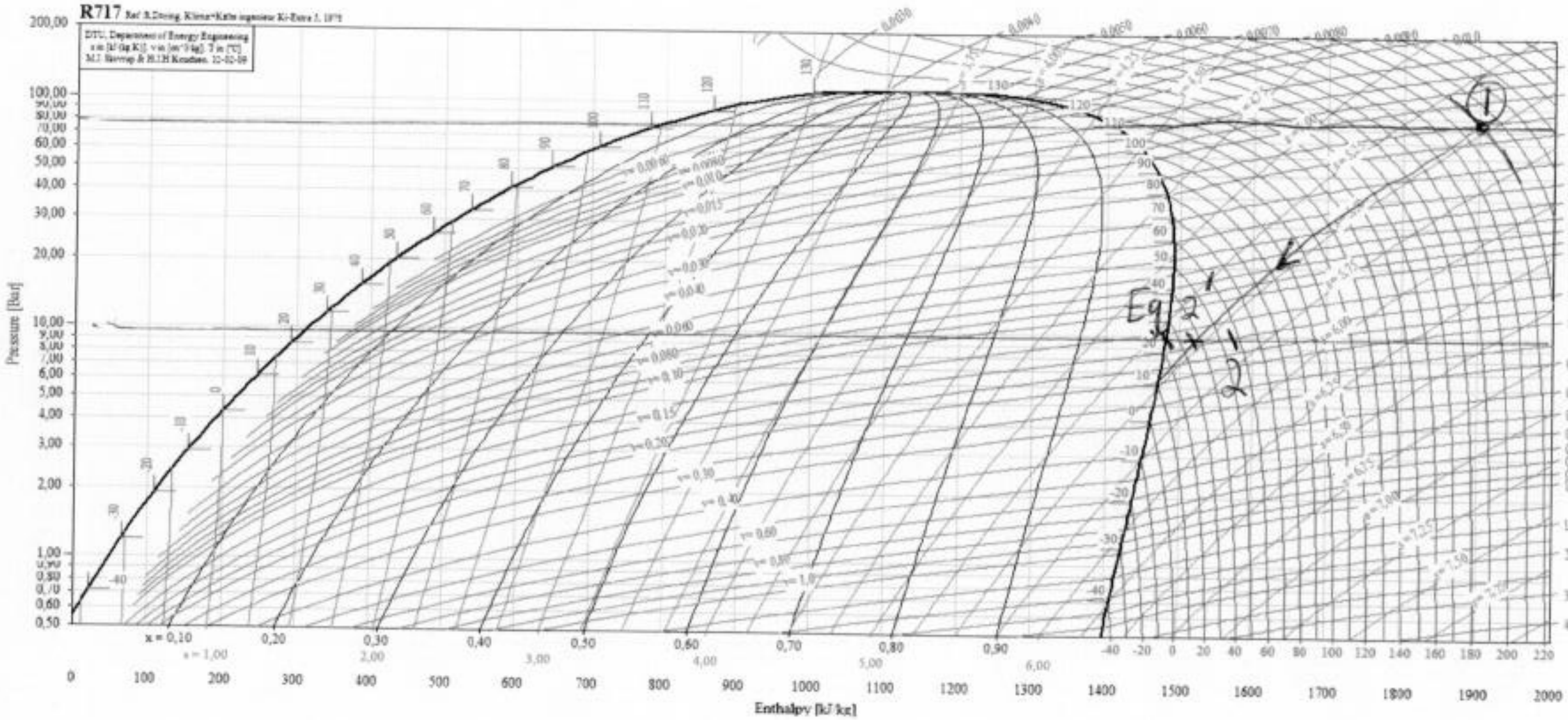
- Find saturation temperature

Solve Fugacity Ratio ⇒ 1

Vary TK

$T_2 = 299\,°K$

| | T K | P MPa | T °C |
|---|---|---|---|
| 1 | 503 | 8 | 230 |
| 2' | 307 | 1 | 34 |
| 2 | 330 | 1 | 57 |
| sat vap | 299 | 1 | 26 |

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