ORDRE DES INGÉNIEURS DU QUÉBEC

SESSION DE MAI 2019

Toute documentation permise Calculatrices : modèles autorisés seulement Durée de l'examen : 3 heures

Total : 20 pts

16-CH-A1 PROCESS BALANCES AND CHEMICAL THERMODYNAMICS

(3 pts) 1. <u>Air conditioning</u>

Air, originally at 39 ^oC and 60 % humidity, is conditioned by being passed through a cooler from which it emerges at 16 ^oC and then through a heat exchanger from which it emerges at 25 ^oC.

a) What is the wet-bulb temperature and humidity content of the original air?

b) What is the wet-bulb temperature and relative humidity of the conditioned air?

c) What is the flow of water (kg/h) that must be removed if 300 m^3/min of air are fed?

4 pts 2. <u>Nitrogen compression</u>

Five moles of nitrogen undergo a quasi-static compression in a piston-cylinder system without friction, from the initial state at P_1 = 100 kPa and T_1 = 88 °C to the final state, P_2 = 300 kPa and T_2 = 88 °C. Initially the system is heated at constant volume to reach the final pressure and then cooled down at constant pressure. **You may consider nitrogen, N_2, as an ideal gas.**

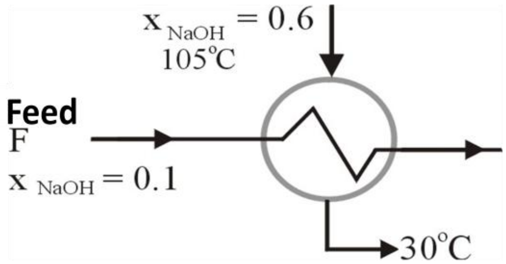
a) Illustrate the process on a *P*-*v* diagram.

b) Compute the following quantities: w_{12}, q_{12}, Δu and Δh (J/g).

c) Compute the variation of the entropy for the system and justify the answer.

4 pts 3. Cooling of caustic soda

In an industrial process, a caustic soda aqueous solution containing 60 mass % is cooled from the temperature of 105 °C to 30 °C by means of a heat exchanger which makes it possible to heat up the feed as illustrated in the following sketch.



Using the attached Figure 2 and on a basis of 1 kg of the stream at $x_{\mathrm{NaOH}} = 0.60$, determine:

a) The fraction of solid NaOH and the liquid composition at the exit of that stream at 30 ^{o}C.

b) The heat exchange during the process assuming that the enthalpy of the solid NaOH is $h_{NaOH(solid)} = 1065 + 3.20(T - T_{ref})\ [=]\ \mathrm{kJ/kg}$ with $T_{ref} = 20^{o}\mathrm{C}$.

3 pts 4. Pressure variation of CO_2

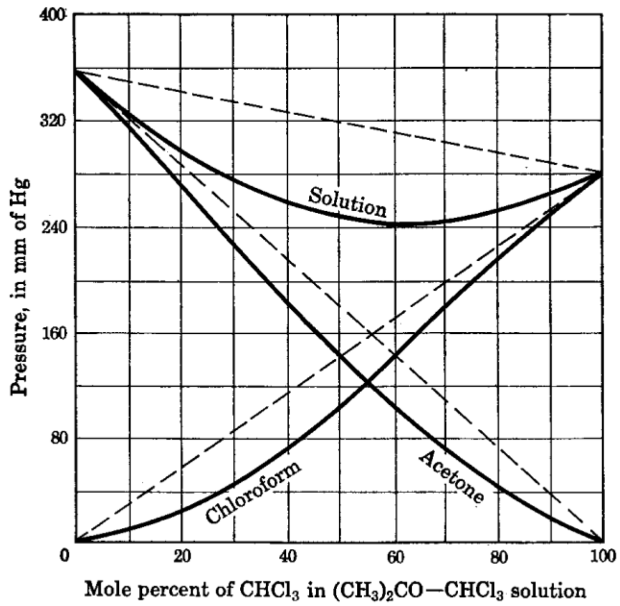
At -90^{o}C, the vapor pressure of CO_2 and its heat of sublimation are:

$$P_{sat} = 38.1 \text{ kPa}$$
$$h_{ig} = 574.5 \text{ kJ / kg}$$
and the gas constant for CO_2, $R = 0.1889 \text{ kJ / kg} \cdot \text{K}$

Using these data and a well-know thermodynamic relation estimate its vapor pressure at 100 K (indicate clearly the required hypotheses).

3 pts 5. Liquid-vapor equilibrium of acetone/chloroform solutions

Equilibrium pressure-composition diagram for the acetone/chloroform system at 35 ^{o}C is given at the following figure.



Equilibrium pressure-composition diagram for the acetone/chloroform system at 35 °C

a) Using this figure determine the vapor pressure and then its fugacity of the pure acetone at its standard state at 35 °C, $f^0_{acetone}\,[=]\,\text{mm Hg}$.

b) Compute the activity and coefficient activity of acetone in a solution containing 50 % mol acetone (state the required hypotheses) and compare to the results for an ideal solution.

3 pts 6. <u>Standard enthalpy of formation for CO</u>

The standard enthalpy of formation of CO cannot be directly measured. However, it can be determined using the two following reactions:

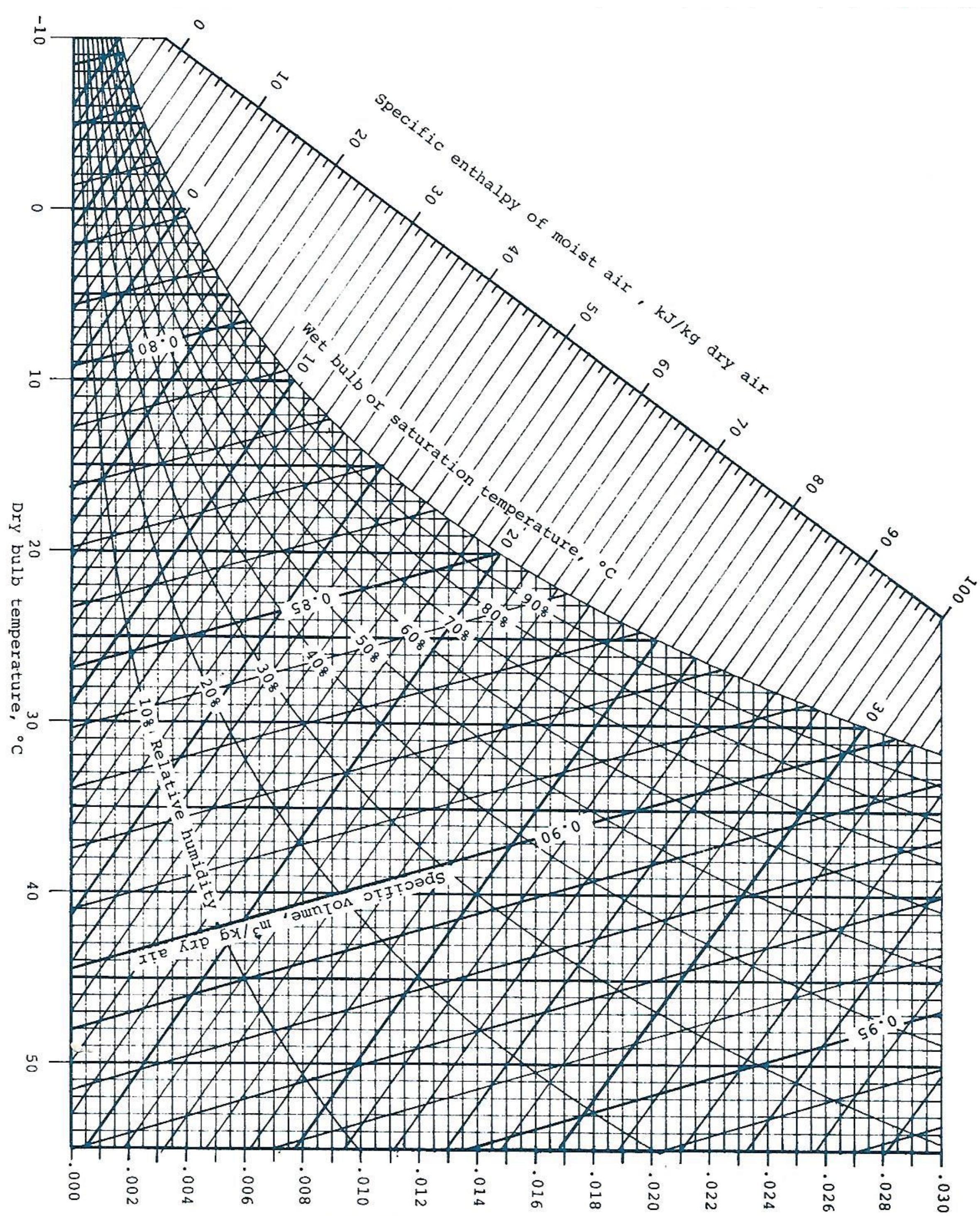
$$\text{C(s)} + \text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)}, \Rightarrow \Delta H^0_{f_{298\,\text{K}}} = \Delta H^0_{r1_{298\,\text{K}}} - 393.1\ \text{kJ/mol}$$

$$\text{CO(g)} + \frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)}, \Rightarrow \Delta H^0_{r2_{298\,\text{K}}} = -282.6\ \text{kJ/mol}$$

a) Using an indirect thermodynamic path, determine the standard enthalpy of formation of CO :

$$\text{C(s)} + \frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{CO(g)}, \Rightarrow \Delta H^0_{f_{298\,\text{K}}} = ???$$

b) Explain in a few words why it is experimentally impossible to measure the standard enthalpy of formation for CO.



Humidity ratio, kg water/kg dry air

Figure 1. Psychometric chart

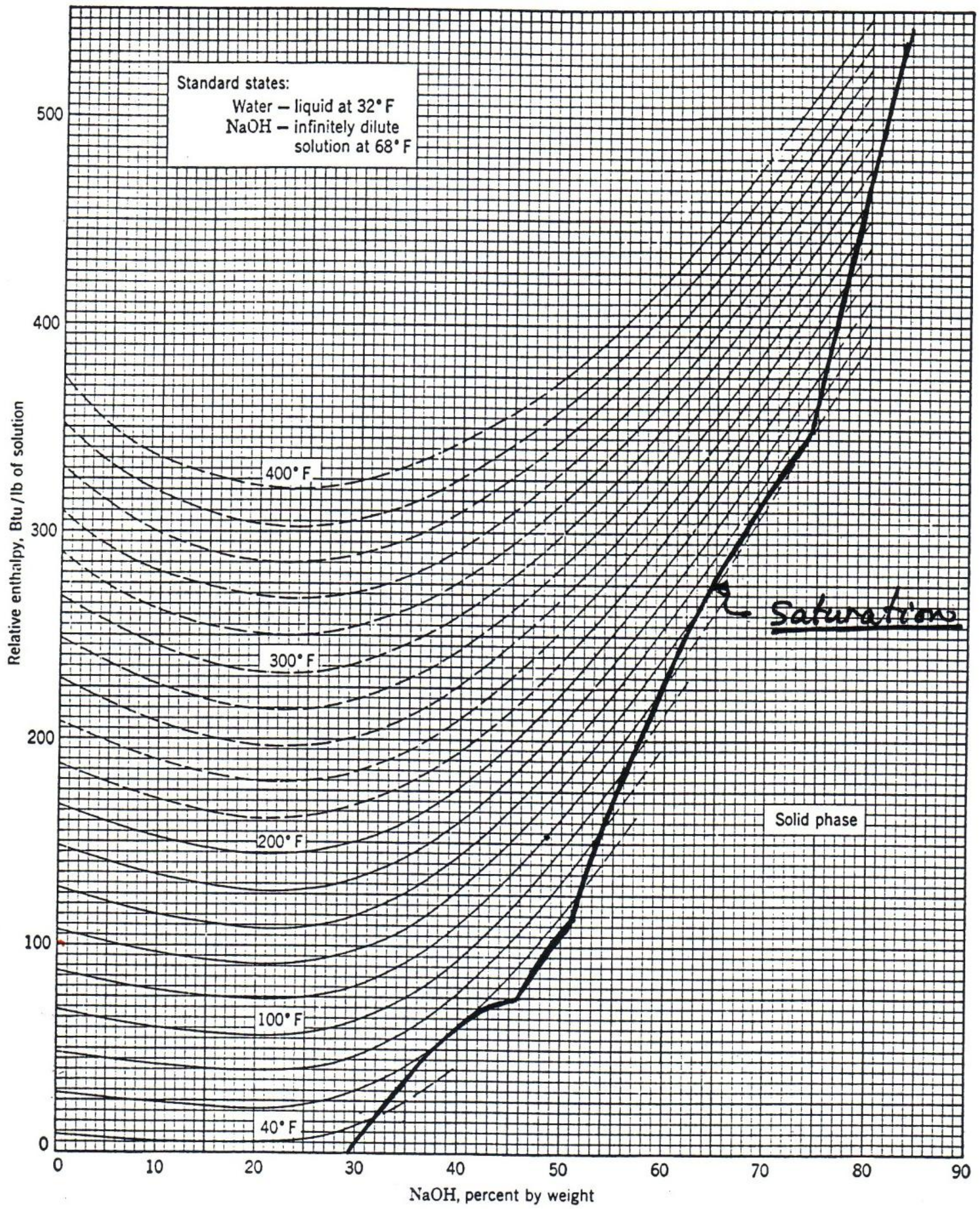


Figure 2. Enthalpy-concentration diagram for aqueous solutions of NaOH

N.B. $1\ \text{BTU/lb}_m = 2.32\ \text{kJ/kg}$

$$\left(x^{o}\text{F-32.2}\right)\frac{5}{9} = y(^{o}\text{C})$$