Chemical Engineering Thermodynamics April, 2005

1. (10%)

A Nigerian teacher invented an award-winning "desert refrigerator" (*Scientific American*, Nov., 2000; see attached page for details). The design consists of an earthenware pot placed inside a larger pot, packed with a layer of damp mud in between these two pos. The refrigerator operates well without electricity in a very dry, well-ventilated environment, so that fresh fruits and vegetables can be stored longer. Please elaborate and comment on how the refrigerator works with what you learn from chemical engineering thermodynamics. You may start from defining the system and its energy balance.

2. (20%)

a) Starting from 1st law, please derive equations describing an adiabatic reversible expansion or compression of an ideal gas (with heat capacities of C_V^*, C_P^*) from P_1 ,T_1 to P_2 ,T_2.

b) Presently, high-pressure air ($\dot{N}$ = 10 mol/s, T = 300 K, p = 10 bar, C_P^* = 29.3 J/mol K) is vented to one atmosphere in the chemical plant that you are working in. Suppose you are considering setting up a turbine to recover waste energy from that stream of high-pressure air. Starting from defining the system, formulating the mass balance, and energy balance, please estimate the power generated from adiabatic, reversible operations of the turbine.

3. (20%)

Please calculate the **volume fraction** and **surface area fraction** of xylene in a mixture with 2,2,4-trimethylpentane (1:1) by using the Table.

Main Group	Subgroup	R	Q
CH2	CH3	0.9011	0.8480
	CH2	0.6744	0.5400
	CH	0.4469	0.2280
	C	0.2195	0.0000
C=C	CH2=CH	1.3454	1.1760
	CH=CH	1.1167	0.8670
	CH2=C	1.1173	0.9880
	CH=C	0.8886	0.6760
	C=C	0.6605	0.4850
ACH	ACH	0.5313	0.4000
	AC	0.3652	0.1200
ACCH2	ACCH3	1.2663	0.9680
	ACCH2	1.0396	0.6600
	ACCH	0.8121	0.3480

4. (15%) Show that the condition for vapor-liquid equilibrium at constant N, T, and P is $\underline{G}^V = \underline{G}^L$, where N is the number of moles and $\underline{G}$ the molar Gibbs free energy.

5. (15%) What are $\Delta \underline{V}_{mix}$, $\Delta \underline{U}_{mix}$, $\Delta \underline{H}_{mix}$, $\Delta \underline{S}_{mix}$, $\Delta \underline{G}_{mix}$, and $\Delta \underline{A}_{mix}$ for mixing of ideal gases at constant temperature and pressure to form an ideal gas mixture? ($\Delta \underline{V}_{mix}$: molar volume change on mixing).

6. (20%) The molar excess Gibbs free energy ($\underline{G}^E$) for binary mixtures at constant T and P is expressed as:

$$\underline{G}^E = Ax_1x_2$$

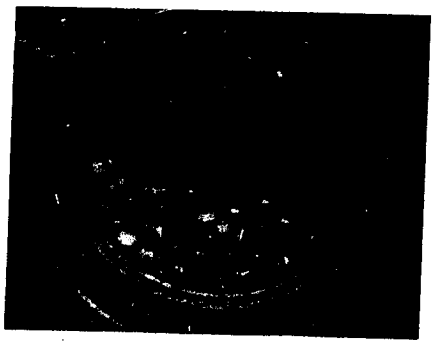
Where A is independent of x, and the standard states are the states of pure components at T and P. Develop expressions for $\ln\gamma_1$ and $\ln\gamma_2$ as functions of composition (x), where γ is activity coefficient. (Hint: $\ln\gamma_i = \overline{G}_i^E/RT$)

Desert Fridge

Cooling foods when there's not a socket around

Thanks to the second law of thermodynamics, Mohammed Bah Abba has developed a refrigerator that doesn't need electricity. What's more, it costs 30 cents to make.

The elegant design consists of an earthenware pot nestled inside a larger pot, packed with a layer of damp sand. When

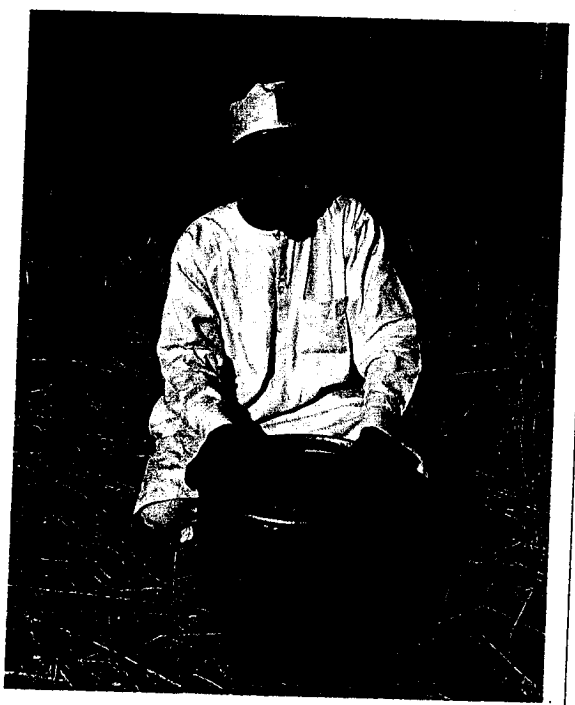


the "Pot-in-Pot" system is stored in a very dry, well-ventilated place, the water held in the pots' clay walls and sand evaporates, carrying heat with it. The inner pot therefore cools down—and makes a useful refrigerator in the northern deserts of Nigeria, where Abba lives and works. Abba says his trials showed that tomatoes would last several weeks instead of several days and that African spinach (amaranth), which normally wilts within hours of harvest, can last up to 12 days. (He's never measured, though, just how many degrees cooler the inner pot becomes.)

Abba's fridge provides an alternative for desert cultures, which generally dry their foods to preserve them. Drying doesn't diminish protein or calorie content much, notes William R. Leonard, a biological anthropologist at Northwestern University who has worked in the high desert of the Peruvian altiplano. "But things like vitamin C are likely to be in shorter supply" in the dried foods, Leonard says. In addition, some foods, such as spinach and onions, cannot be dried, remarks Abba, a lecturer at Jigawa State Polytechnic in Dutse, Nigeria. The Pot-in-Pot may have great social impact, too: Abba says that young girls who used it would not have to sell their families' freshly picked foods right away and thus would have time to go to school.

For his work, Abba received one of five biennial Rolex Awards for Enterprise on September 27. The others were Elizabeth Nicholls, a Canadian paleontologist who unearthed an ichthyosaur in British Columbia; Maria Eliza Manteca Oñate, an Ecuadorian environmentalist promoting sustainable farming in the Andes; Laurent Pordié, a French ethnopharmacologist who is preserving traditional Tibetan healing methods in northern India; and David Schweidenback, an American recovering used bicycles in the U.S. for shipment to developing countries (see www.rolexawards.com).

—*Naomi Lubick*



POT-IN-POT system developed by Mohammed Bah Abba (*above*) consists of nested clay pots cooled by evaporation from an intervening layer of wet sand (*left*).

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