Physical Chemistry of Interfaces: Exercises

2nd session

2.1 (following **1.3**) The droplets of mercury are deposited on the glass plate. What is the vapor pressure over the droplets at T = 20 °C if their diameter is equal to 1 mm, 0.01 mm or de 0.0001 mm?

($\gamma_{Hg} = 484\ mNm^{-1}$ at $T = 20\ ^\circ C$, $M_{Hg} = 200.6\ gmol^{-1}$, $\rho_{Hg} = 13.5\ gcm^{-3}$, $p_{Hg}^* = 0.1713\ Pa$ at $T = 20\ ^\circ C$)

2.2 Soap bubbles are formed from the air which is slightly warmer than the ambient air. Determine the minimal temperature difference at which the bubbles can rise in the air if:

   a) the liquid weight is neglected;

   b) weight of the liquid film is taken into account; the thickness is ε=50 nm and density is equal to the water density.

 Given values: $T_{amb} = 298\ K$, $p_{amb} = 1\ bar$, radius of the bubble r=1 cm, surface tension of the soap solution $\gamma = 0.04\ J/m^2$. We assume that the air obeys the ideal gas law.

2.3 See following page.

CH-242(b) - Homework problem 2.3

Capillary condensation and pore size measurement

Everyone is familiar with the small packets of silica gel included in the sealed packaging of certain food products:


When you open these packets, you will find many small beads of silica, shown next to the packet in the image above. Thanks to their rough and porous nanostructure, these beads are able to absorb significant quantaties of water, keeping the environment dry inside the food packaging and thus helping preserve the food product. Here is a scanning electron micrograph showing the extreme surface roughness on the nanoscale:
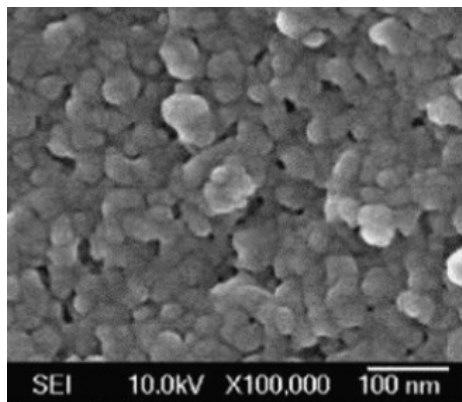
This absorptive capability derives in large part from the effect of capillary

condensation, discussed in section 5.1 of the Lecture 1 notes. In this problem we explore how by exploiting the effect of capillary condensation one can measure the size of the porous structures at the silica surface.

As a very rough approximation we model the porous structure of the silica bead surface as a vast array of tiny cylindrical "nano-pores" with depth h and radius r. Here is a diagram of one such nanopore:
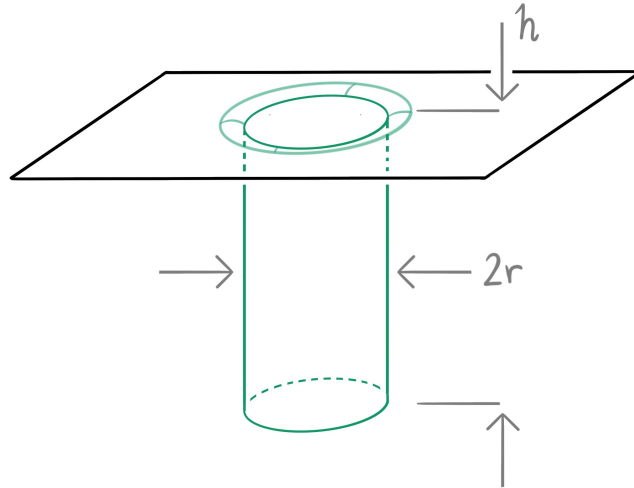
Part A

At what pressure P'_o will gaseous vapor begin to completely fill up the nanopore? Express your answer in terms of the surface tension γ of the fluid, the vapor pressure P_o of the flat interface, the molar volume V_m of the liquid, and the ambient temperature T of the nanopore. Assume that the nanopore is wetting with respect to the fluid so that the liquid makes a contact angle $\theta = 0°$ at the nanopore. Draw a diagram with the fluid half-way filling the nanopore.

Part B

At pressures below P'_o, will there be any liquid in the nanopore? If so, draw a diagram illustrating the distribution of liquid in the nanopore.

Part C

Assuming the height h of the nanopore is much larger than the nanopore radius r, make a qualitative graph describing the volume of liquid absorbed in the nanopore as a function of the ambient pressure P, with $0 < P < P_o$. Assume that $P'_o = \frac{1}{2}P_o$.

Part D

Here is a graph[1] of the volume liqiuid nitrogen absorbed by a sample silica particles as a function of the ambient pressure of (gaseous) nitrogen:

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[1] D. Dollimore and G. R. Heal, Journal of Applied Chemistry 14, 109 (1964).
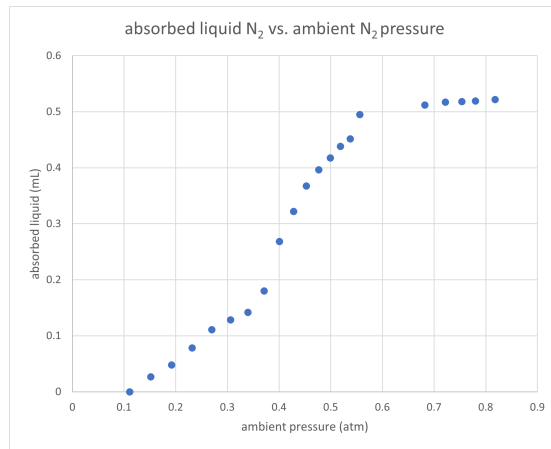
Suppose that the nanopore is held at a temperature of $-198.5\ ^\circ$C, which is boiling point of liquid nitrogen at a pressure of 1 atm. Given that the surface tension of liquid nitrogen is 9 mN m^{-1} and its density is 0.8 g mL^{-1}, estimate the average nanopore radius of the silica particles.