Introduction to Physical Chemistry

Physical Chemistry Tutorials
Mark Wallace, Wadham College
mark.wallace@chem.ox.ac.uk
CRL Floor 1 Office 1 Phone (2)75467

Part I: Revision

Answer each question briefly; one paragraph at most. Be prepared to discuss these topics in the tutorial.

1) Describe the main phases in which matter can exist. What are the main characteristics? How would you experimentally determine in which phase your sample is? How would you quantify the differences between the phases?
2) In which way do the forces between atoms or molecules determine the phase of a substance?
3) What are the differences between real and ideal gases? Provide an equation of state (relating Pressure, Volume, and Temperature) for a real gas and interpret the terms that take into account the differences between a real and ideal gas. Comment on the extreme limits (e.g. zero temperature). What is the idea of the "virial expansion"?
4) How would your relate the pressure of a gas and the force exerted on the walls of a container to the microscopic processes involving individual atoms or molecules? A calculation is not required (you are welcome to try!). How can we relate microscopic to macroscopic properties of a gas?

Part II: Questions

Please attempt each question in this section.

1) Ideal Gas
   a. A meteorological balloon has a radius of 1.0 m when released at sea level at 20°C and expands to a radius of 3.0 m when it has risen to its maximum altitude, where the temperature is -20°C. What is the pressure inside the balloon at that altitude?
   b. A vessel of volume 22.4 litres contains 2 mol H_2 and 1 mol N_2 at 273.15 K. All the H_2 reacted with sufficient N_2 to for NH_3. Calculated the partial pressures and the total pressures of the final mixture.
2) Freezer

   I just bought a new freezer. When I first close the 1 m^2 door the volume of the freezer is 1 m^3 and the contents are at room temperature (20°C). I wait until the freezer cools to -10°C. Assuming ideal gas behaviour, and no exchange of gas, what force is required to open the door?
3) Drinking Straw

   What pressure difference must be generated across the length of a 15cm vertical drinking straw in order to drink water?
4) Barometric Formula

   The barometric formula ($p = p_0 \exp[-Mgh/RT]$) relates the pressure of a gas of molar mass M at some altitude h to its pressure p_0 at sea level. Derive this relation by showing that the change in pressure dp for an infinitesimal change in altitude dh is $dp = -\rho g dh$ (where ρ is density). Remember ρ depends on pressure.

Ignoring temperature variations, evaluate the pressure difference between the top and bottom of

a. A cup of tea, height 15 cm.

b. The London eye, height 135 m.

Part III: Supplementary Question

5) The Maxwell-Boltzmann distribution function of molecular speeds in a gas has the form:

$$dF(c) = 4\pi\left(\frac{m}{2\pi k_B T}\right)^{3/2} c^2 \exp\left(-\frac{mc^2}{2k_B T}\right)dc$$

where $dF(c)$ is the fraction of molecules with speeds between c and c + dc, m is the mass of a molecule and T is the temperature.

a. Sketch the form of this distribution and calculate the fraction of Argon atoms (mass 6.64 x 10-26 kg) with speeds between 100 ms^{-1} and 100.5 ms^{-1} at 298 K.

b. Derive an equation for the most probable speed of a molecule c_p, and use this to find c_p for the same argon atoms.

c. Derive an equation for the mean speed of a molecule c_m. Calculate c_m for the argon atoms.

d. Why do the values for c_p and c_m differ? Compare the value of the root mean square speed c_{rms} for argon atoms.

You may need the following standard integral:

$$\int_0^\infty x^3 e^{-ax^2} = \frac{1}{2a^2}$$