THERMAL AND KINETIC PHYSICS (PHY 214)

Coursework 10: Week 11

ISSUE: Tuesday 07 December, 2010 HAND-IN: Tuesday 14 December, 2010

Students name (top left corner), course title & exercise number and exercise group (top right corner) should appear on every sheet of the submitted coursework and sheets should be firmly held together. A stapler is available if needed from the secretary's office.

Hand-in of worked exercises must take place by 4:00 p.m. on the above date at the labeled box provided outside the Teaching Administrators office on the first floor.

This time will be strictly adhered to and no late working will be accepted without written explanation to the course organiser. The solutions will appear shortly after this time on the TKP website.

Each coursework is worth 40 marks and the aggregate coursework mark will count 10% towards the final mark. An indicative mark scheme is given with each question. **Note**: ***I want to see the method of solution. No credit will be given for simply writing down the answer.***

Students should collect new exercise sheets in the Tuesday lecture or download them from the Web. Marked exercises will be returned in exercise classes or via the box outside the Teaching Administrators office on the first floor.

QUESTION 1: (10 Marks)

The Clausius-Clapeyron equation for the slope of the liquid-vapour co-existence curve may be written as

$$\frac{dP}{dT} = \frac{\ell^{L\to V}}{T\left(v^V - v^L\right)}$$

where the superscripts L and V refer to liquid and vapour phases respectively, v is the volume per unit mass of material and $\ell^{L\to V}$ is the latent heat of vaporization per unit mass.

The volumes per unit mass of water and steam at 100 ^{o}C and at a pressure of 1 atm are 1.043 (10^{-3}) m^3 kg^{-1} and 1.673 m^3 kg^{-1} respectively. The latent heat of vaporisation is 2.257×10^6 J kg^{-1} .

a) If we want to increase the boiling point in a pressure cooker from 100 ^{o}C to 106 ^{o}C, estimate how much increase in pressure will be needed and what pressure the cooker will need to withstand (in atmospheres). **[5mks]**

b) Pressure falls off exponentially as height, *h*, above sea level is increased according to the formula

$$P = 1.00 atm \times \exp\left(-1.33 \times 10^{-4} m^{-1} h\right).$$

Canary Wharf main tower is 244m high. At what temperature does water boil at the top of the tower? Give your answer to 2 decimal places in degrees Celsius.

[5mks]

QUESTION 2: (20 marks) (From question 6 of the 2005 examination paper)

The Maxwell speed distribution function for a gas of molecules of mass *m* in equilibrium at temperature *T* has the form

$$P(v) = \left(\frac{m}{2\pi k_B T}\right)^{3/2} 4\pi v^2 \, exp\left(\frac{-mv^2}{2k_B T}\right)$$

where v is the molecular speed.

(a) The mode speed or most probable speed v_m is defined as the value of v at which $P(v)$ has its maximum value. Show that

$$v_m = \left[\frac{2k_B T}{m}\right]^{1/2}$$ **[5mks]**

(b) Give an expression for the value $P(v_m)$ of the speed distribution function $P(v)$ evaluated at the mode speed, $v = v_m$ **[5mks]**

(c) A gas, in equilibrium at temperature T , consists of a mixture of helium atoms (atomic weight 4 amu) and argon atoms (atomic weight 40 amu). On a single set of axes sketch separately the Maxwell speed distribution function for the helium and for the argon atoms. **[5mks]**

(d) The mixture of helium and argon described above has equal number densities of helium and argon and is held in a container with a porous wall surrounded by an evacuated chamber. Assuming that effusion occurs through the porous wall, determine for the escaped gas mixture in the outside chamber, the ratio of the number of molecules of helium to the number of molecules of argon. **[5mks]**

QUESTION 3: (10 marks)

Radon is a radioactive gas produced by the nuclear decay of naturally occurring Uranium in the Earth's interior. It seeps out of the Earth at a steady rate, can accumulate in cellars, basements or sealed underfloor spaces in buildings and is thought to be a health risk in certain areas of Britain. **Its mass is 222 amu, its atomic diameter is approximately 3×10^{-10} m and its half-life is about 3.8 days.**

Estimate how far an atom of Radon in still air at a temperature of 285 K will travel by diffusion during its half-life. **[10mks]**