Constants or equations that you might need	
PV= nRT for all gases discussed in this test R (gas constant) = 8.314 J mol^{-1} K^{-1}, 0.082 L atm mol^{-1} K^{-1} k (Boltzmann constant) = 1.381 x 10^{-23} J K^{-1} N_{av} = 6.02 x 10^{23} molecule mol^{-1}	1 atm = 760 Torr = 101300 Pa = 1013 hPa 1 ppmv = 1 x 10^{-6} mol/mol=1 x 10^{-6} atm/atm Pa = Nm^{-2}

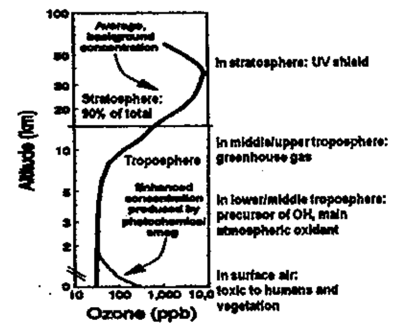

Figure 1-1.

1. Atmospheric ozone plays different roles based on the location as shown in **Figure 1-1**. However, the formation of ozone at the stratosphere and troposphere is very different.
   a) (12 pts) The ozone formation over the stratosphere is based on the Chapman mechanism. Please describe **in detail** the major four reactions of the Chapman mechanism.
   b) (10 pts) The sources of tropospheric ozone can be contributed via transferring from the stratosphere and chemical reactions happening in the troposphere. For the transport part, it can be estimated using a two-box model as shown in Figure 1-2. The residence time of air in the stratosphere is $\tau_S = 1/k_{ST}$ = 1.3 years. **Please use the two-box model as shown in Figure 1-2 to estimate the residence time ($1/k_{TS}$) of air in the troposphere** (hints: mass balance equations for two boxes for air mass).
   c) (12 pts) In the troposphere, ozone pollution is mainly produced by chemical reactions. **Figure 1-3** shows the cycling of HO_x and O_3 production in a polluted atmosphere. Please describe **in detail** how the ozone is formed in the troposphere.

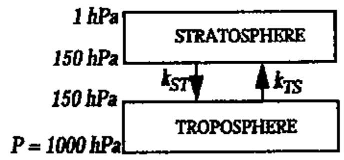

Figure 1-2. Two-box model for stratosphere-troposphere exchange

2. (a) (10pts) Please use **Figure 2-1** or your favorite method to derive the Barometric Law, which should show how the pressure of air changes with altitude (z) in the following formula
   $P(z) = P(0)\, e^{(-z/H)}$,
   where $H=RT/(M_a\, g)$, is the scale height; R is gas constant, T is temperature assumed to be constant with altitude, M_a is the molecular weight of air and g is the acceleration of gravity.
   (b) The Barometric law can be applied to explain the sea-breeze circulation. On a sunny daytime, the wind is likely to blow from sea to land. Taiwan is an island, sea-breeze is very common during a sunny daytime and can affect the distribution of pollutants. Let's use a two-box model to estimate the mixing ratio of CO(一氧化碳) during daytime with a constant horizontal wind of speed u =2 m/s as shown in **Figure 2-2.** The two boxes have the same land surface like a square, 10km×10km. The mixing height of the boxes is h = 0.5 km. Box one is an urban area with CO emission rate of E = 0.3 moles/km^2-s while Box two is a rural area with no local CO emission (i.e., E=0). The mixing ratio of CO, C_{co}, over the sea ($x \le 0$) is assumed to be 0.1 ppmv. Assume that there is no chemical production or chemical loss or deposition for CO.
   (i) (6pts) Please write the mass balance equations of CO for the two boxes (note: make sure the units are consistent).
   (ii) (6pts) Assume steady-state for both boxes, please calculate the CO mixing ratio for the two boxes, respectively.
   (iii) (10pts) Please use a puff(column) model to derive the mixing ratio of CO varies as a function of x.
   (iv) (4pts) please plot the result of (iii) for x = 0 to 20 km.

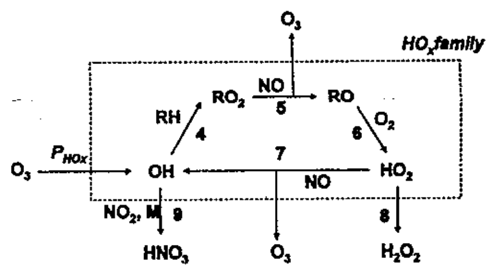

Figure 1-3.

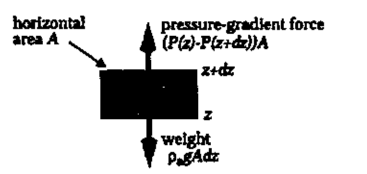

Figure 2-1 vertical forces acting on an elementary slab of atmosphere. ρ_a is the density of air.

3. PM2.5 is one of the major air pollutants globally and is composed of various chemical species. EPA-Taiwan provides the emission data on the website for the whole Taiwan. The total emission is 1.2×10^8 Kg/yr for SO_2 and 4.0×10^8 Kg/yr for NOx (assuming as NO_2 for this exam) over the Taiwan island (此為台灣總排放量)(Atomic weight: S(32g/mole), N (14g/mole), O (16g/mole), H (1g/mole)).
   (a) Consider only local emissions. We assume that all of the emitted NOx and SO_2 are precipitated back over Taiwan as HNO_3 (1 mole of NOx forms 1 mole of HNO_3) and H_2SO_4 (1 mole of SO_2 forms 1 mole of H_2SO_4), respectively. The area of Taiwan is 36200 km^2 and the mean precipitation rate is 7 mm day^{-1} (based on CWB data). Assume that HNO_3 and H_2SO_4 are the only impurities in the rainwater,
   (i) (4 pts) please calculate the total amount of rain over the whole Taiwan per day (in a unit of liter day^{-1}).
   (ii) (6 pts) please calculate the concentration of HNO_3 and H_2SO_4 in the rain respectively (in a unit of M, 體積莫爾濃度).
   (iii) (4 pts) please calculate the resulting rainwater pH (assuming equilibrium with H_2SO_4 and HNO_3, H_2SO_4 and HNO_3 are strong acids and dissociate completely).
   (iv) (6 pts) In general, the pH of rain over Southern Taiwan is higher than in Northern Taiwan. Please explain the possible reasons by considering only local emissions.
   (b) (10 pts) Please describe at least two impacts of PM2.5 and acid rain on the environment or ecosystem, respectively.

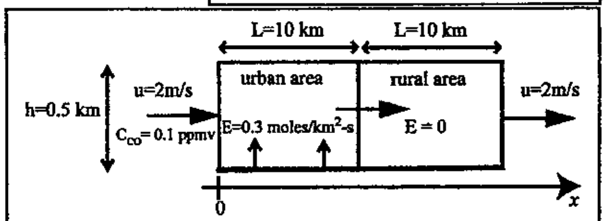

Figure 2-2