Problem Set

Assigned August 30, 2013 – Due Friday, September 6, 2013

Please show all work for credit

Calculus and Units

1. For the following expression, determine what the final units be in terms of S.I. or S.I. derived units.

\[ nRT \int_{V_i}^{V_f} dV \frac{1}{V} \]

Where \( n \) is number of moles, \( R \) is the gas constant, \( T \) is temperature, and \( V \) is volume.

2. For the following expression, determine what the final units be in terms of S.I. or S.I. derived units.

\[ \frac{dE}{dP} \]

Where \( E \) is energy and \( P \) is pressure.

3. For the following expression, determine what the final units be in terms of S.I. or S.I. derived units.

\[ \frac{dE}{dV} \]

Where \( E \) is energy and \( P \) is pressure.

Kinetic Energy

4. The average speed of a K atom in a molecular beam is measure to be \( 629 \text{ m/s} \). Calculate the kinetic energy of a K atom in the beam.

5. Assuming that the molecules in the beam move one dimensionally, what is the temperature of the beam?
Gas Laws

6. Problem 1.11 in Engle P. Chem Life Science (photosynthesis)
As a result of photosynthesis, 1.0 kg of carbon is fixed per square meter of forest. Assuming air is 0.046% CO$_2$ by weight, what volume of air is required to provide 1.0 kg of fixed carbon? Assume $T = 298$ K and $P = 1.00$ atm. Also assume that air is approximately 20% oxygen and 80% nitrogen by weight.

7. Problem 1.13 in Engle P. Chem Life Science (Hemoglobin problem)
One liter of fully oxygenated blood can carry 0.20 L of O$_2$ measured at $T = 273$ K and $P = 1.00$ atm. Calculate the number of moles of O$_2$ carried per liter of blood. Hemoglobin, the oxygen transport protein in blood, has four oxygen-binding sites. How many hemoglobin molecules are required to transport the O$_2$ in 1.0 L of fully oxygenated blood?

8. Problem 1.17 in Engle P. Chem Life Science (Carbon monoxide problem)
Carbon monoxide (CO) competes with oxygen for binding sites on the transport protein hemoglobin. CO can be poisonous if inhaled in large quantities. A safe level of CO in air is 50 parts per million (ppm). When the CO level increases to 800 ppm, dizziness, nausea, and unconsciousness occur, followed by death. Assuming the partial pressure of oxygen in air at sea level is 0.20 atm, what ratio of O$_2$ to CO is fatal?

The photosynthetic formation of glucose in spinach leaves via the Calvin cycle involves the fixation of carbon dioxide with ribulose 1-5 diphosphate $C_5H_8P_2O_{11}^{4-}(aq)$ to form 3-phosphoglycerate $C_3H_4PO_7^{3-}(aq)$:

$$C_5H_8P_2O_{11}^{4-}(aq) + H_2O(l) + CO_2(g) \rightarrow 2C_3H_4PO_7^{3-}(aq) + 2H^+(aq)$$

If 1.00 L of carbon dioxide at $T = 273$ K and $P = 1.00$ atm is fixed by this reaction, what mass of 3-phosphoglycerate is formed?

10. Problem 1.8 in Atkins P. Chem (9th) (compressibility problem)
At 273 K measurements on argon gave $B = -21.7$ cm$^3$ mol$^{-1}$ and $C = 1200$ cm$^6$ mol$^{-2}$, where $B$ and $C$ are the second and third virial coefficients in the expansion of $Z$ in powers of $1/V_m$. Assuming that the perfect gas law holds sufficiently well for the estimation of the second and third terms of the expansion, calculate the compression factor of argon at 100 atm and 273 K. From your result, estimate the molar volume of argon under these conditions.
11. Problem 1.20 in Atkins P. Chem (9th) (van der Waals)
The equation of state of a certain gas is given by \( p = \frac{RT}{V_m} + \frac{a + bT}{V_m^2} \), where \( a \) and \( b \) are constants. Find \( (\partial V/\partial T)_p \).

12. Problem 1.22 in Atkins P. Chem (9th) (compressibility)
Derive an expression for the compression factor of a gas that obeys the equation of state
\( p(V - nb) = nRT \), where \( b \) and \( R \) are constants. If the pressure and temperature are such that \( V_m = 10b \), what is the numerical value of the compression factor?