Chemistry 231 **<u>Assignment #1</u>** (due Tuesday, 21 September, in class)

As a professional courtesy, please:
- answer the questions in the order provided
- write your answers only on one side of each page
- leave some blank spaces for comments

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1. For math practice, give the ordinary derivatives (df/dx) of the following functions:

a) $f(x) = -(10 - x)^2$

[3] **b)** $f(x) = 15x/(x - 3)$

c) $f(x) = a_0 + a_1 x + a_2 x^2$ (a_0, a_1, a_2 are constants)

2. Evaluate the following integrals:

[3] **a)** $\int_1^3 \frac{12}{x}\,dx$ **b)** $\int_1^3 \frac{12}{x^2}\,dx$ **c)** $\int_{-1}^3 (a_0 + a_1 x + a_2 x^2)\,dx$

3. The **Stefan-Boltzmann law** gives

$$p = \beta T^4 \qquad (\beta = 2.522 \times 10^{-16}\ \text{Pa K}^{-4})$$

for the pressure of thermal radiation (a "photon gas") at temperature T.

a) For thermal radiation, why is it permissible to replace the **partial derivative** $(\partial p/\partial T)_V$ with the **ordinary derivative** dp/dT ?

[3] **b)** Use the thermodynamic equation of state $\left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial p}{\partial T}\right)_V - p$

to show $(\partial U/\partial V)_T = 3p$ for thermal radiation.

c) Does the energy of thermal radiation increase if it is compressed ($\Delta V < 0$) isothermally? Briefly justify your answer.

4. The **van der Waals equation** gives $p = \frac{RT}{V_m - b} - \frac{a}{V_m^2}$ for the pressure of a nonideal gas.

a) Use $\left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial p}{\partial T}\right)_V - p$ to show $\left(\frac{\partial U}{\partial V}\right)_T = \frac{a}{V_m^2}$ for a gas described by the van der Waals equation of state.

[3] **b)** Does the energy of the gas increase if it is compressed isothermally? Justify your answer.

c) Prove a gas described by the van der Waals equation becomes ideal in the limit $p \to 0$.

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5. **a)** The van der Waals *a* parameter for Ar (1.36 bar L^2 mol^{-2}) is significantly larger than *a* for He (0.0346 bar L^2 mol^{-2}). Why?

[2] **b)** The van der Waals *b* parameter for Ar (0.0320 L mol^{-1}) is significantly larger than *b* for He (0.0238 L mol^{-1}). Why?

6. The gravitational energy of mass *m* at elevation *h* above sea level is $U_g = mgh$. Near the surface of the earth, the gravitational acceleration is $g = 9.81$ m s^{-2}.

a) Calculate the change in gravitational energy (ΔU_g) for 5.00 kg of water flowing over Niagara Falls, a drop of 51.0 m.

[2] **b)** The average flow rate of the Niagara River is 5.80×10^6 kg s^{-1}. Calculate the power that could be generated if all the water flowing over the Falls is used to produce hydroelectricity. Give your answer in Watts, the SI unit of power (1 W = 1 J s^{-1}).

7. A 50.0 L tank is filled with methane at −100 °C. A pressure gauge on the tank reads 100.0 bar.

a) Calculate the number of moles of methane in the tank using the ideal gas equation.

b) Repeat part **a** using the compression factors for methane plotted below.

[4] **c)** Explain why the calculation in part **b** is more reliable than the calculation in **a**.

d) Do repulsive CH_4-CH_4 intermolecular forces dominate attractive CH_4-CH_4 forces at −100 °C and 100.0 bar? Justify your answer.