59-240 Introductory Physical Chemistry I — **Mid-Term #1**
University of Windsor — **October 17, 2001 in Class, 9:30 - 10:20**

Instructions:
There are five questions in total. Complete the first question, and then complete three of the four remaining questions. Each question is worth 25% of the total mark (i.e., 5 marks out of a total possible 20 marks). There is a bonus question at the end worth an additional 2 marks that you may attempt if you have time remaining. Place all answers in the test booklets provided. Please refer to the attached information sheets for physical constants and useful equations. Good luck!

1. (**5 marks**, you must complete this question) For the systems below, state whether q, w, ΔH and ΔU are positive, negative or equal to zero. Please include your reasoning for each situation.

   a) Reversible freezing of water at 1 atm and 0°C
   b) Reversible isothermal compression of a perfect gas
   c) Adiabatic expansion of a perfect gas into a vacuum
   d) Reversible heating of a perfect gas at constant volume
   e) Reversible heating to make the phase transition from grey tin (solid, with density $\rho = 5.75 \text{ g cm}^{-3}$) to white tin (solid, $\rho = 7.31 \text{ g cm}^{-3}$) at constant pressure.

2. (**5 marks**) 301 g of gaseous ethane, C_2H_6(g), is contained within a 4.860 L container at 27°C. What pressure is exerted by the gaseous ethane if it behaves as (a) a perfect gas, and (b) as described by the van der Waals equations of state? (c) Calculate the compression factor in the latter case. Does this compression factor result from attractive or repulsive intermolecular forces? Explain. For ethane $a = 5.562 \text{ L}^2 \text{ atm mol}^{-2}$ and $b = 0.06380 \text{ L mol}^{-1}$.

3. (**5 marks**) A sample of 2.5 mol of a perfect gas at 220 K and 200 kPa is compressed reversibly and adiabatically until the temperature reaches 255 K. (a) Given that the molar constant-volume heat capacity is $C_{V,m} = 27.6 \text{ J K}^{-1} \text{ mol}^{-1}$, calculate q, w, ΔU and ΔH. (b) Assuming you started with 22.9 L of gas, what is the final volume of the gas from this type of compression?

4. (**5 marks**) A bomb calorimeter (constant volume) has a calorimeter constant $C = 69.3 \text{ J K}^{-1}$, where $|q| = C\Delta T$. (a) How much will temperature rise in the calorimeter if 0.135 g of phenol, C_6H_5OH(s), is burned in the calorimeter? For phenol, $\Delta_c H^o = -3054 \text{ kJ mol}^{-1}$ and MW = 94.12 g mol^{-1}. (b) What is the standard enthalpy of formation of phenol, $\Delta_f H^o(C_6H_5OH, s)$, if $\Delta_f H^o(CO_2, g) = -393.51 \text{ kJ mol}^{-1}$, $\Delta_f H^o(H_2O, l) = -285.3 \text{ kJ mol}^{-1}$ and $\Delta_f H^o(O_2, g) = 0.0 \text{ kJ mol}^{-1}$?

5. (**5 marks**) The isothermal compressibility of copper, κ_T, at 293 K is $7.35 \times 10^{-7} \text{ atm}^{-1}$. Write an expression in terms of pressure and density, and then calculate the pressure that must be applied to increase its density by 0.08 per cent. Recall that $V = m/\rho$ and $dV = -(m/\rho^2)d\rho$, where ρ is density.

6. (**2 marks** - Bonus Question) Demonstrate that for a perfect gas that $\alpha = 1/T$ and $\kappa_T = 1/p$.

End of Mid-Term #1