Multiple Choice (15 points each, written justification may lead to partial credit on wrong answers)
1. If heat is added to an ideal gas while it is compressed, which of the following will be true for the gas?
   A) internal energy must decrease  
   B) w must be greater than zero  
   C) internal energy is unchanged  
   D) q must be less than zero  
   E) none of the above

2. What is the efficiency of an engine (Carnot cycle) running between 700K and 300K?
   A) 0.000  
   B) 0.429  
   C) 0.571  
   D) 0.700  
   E) 2.33

3. What is the measured potential $\varepsilon$ for a Cu (s) | Cu$^+$ (1M) || Cu$^+$ (0.01 M) | Cu (s) galvanic cell?
   A) $(RT/F) \ln 100$  
   B) $(RT/F) \ln 10$  
   C) $(RT/F) \ln 1$  
   D) $(RT/F) \ln 0.10$  
   E) $(RT/F) \ln 0.01$

4. Which of the following will have the highest osmotic pressure if 3 g are dissolved in 1 L of water?
   A) acetone, C$_3$H$_6$O  
   B) polyethylene, (CH$_2$)$_n$ $n>500$  
   C) methanol, CH$_3$OH  
   D) butanol, C$_4$H$_9$OH  
   E) cesium hydroxide, CsOH

5. When the ln [A] is plotted versus time you get a straight line. What order is this reaction with respect to [A]?
   A) 0  
   B) 1  
   C) 2  
   D) 3  
   E) can not be determined

6. As temperature of the system is increased, what happens to the entropy of the system, $S_{sys}$, in general?
   A) always increases  
   B) remains unchanged  
   C) always decreases  
   D) increases only at phase transitions  
   E) can not be determined

Problems (30 points each, show all work)
7. One mole of an ideal gas initially at 38°C and 1.00 atm pressure is allowed to expand reversibly at constant pressure while it is heated until the final temperature is 392°C. For this gas, $C_v = 20.8 \text{ J K}^{-1} \text{ mol}^{-1}$ and this is considered constant over the 0°C to 400°C temperature range. Calculate the work, $w$, done on the gas in this expansion. Calculate $\Delta E$ and $\Delta H$ for this process. What is the amount of heat, $q$, absorbed by the gas. $R = 0.0820578 \text{ L atm mol}^{-1} \text{ K}^{-1} = 8.31451 \text{ J mol}^{-1} \text{ K}^{-1}$.

8. Consider a fertilized hen egg in an incubator—a contant temperature and pressure environment. In a few weeks the egg will hatch into a chick. In the egg, hen proteins are formed into a highly ordered chick. Does the entropy of the system increase or decrease (define system carefully here)? Does this violate the 2nd law of thermodynamics? Explain in 2 or 3 sentences why the development of the chick is or is not consistent with the 2nd law.
9. A saturated solution is prepared by mixing 0.1 mol of PbO and 0.1 mol of PbS in 100.0 mL of distilled water. Calculate the final concentration of all species in solution (Pb$^{2+}$, O$^{2-}$ and S$^{2-}$) given that $K_{sp,PbO} = 3.0 \times 10^{-20}$, $K_{sp,PbS} = 6.0 \times 10^{-19}$.

10. What pressure is required at 25˚C to freeze a compound which has MW = 100 amu, normal melting point of 0˚C, normal boiling point of 123˚C, $\Delta H_{\text{fus}} = -100$ kJ/mol, $\Delta H_{\text{vap}} = 550$ kJ/mol, liquid density of 0.821 g/mL and solid density of 1.521 g/mL?

11. Given the following mechanism, derive a rate law (d[P]/dt) expressed only in terms of [A], [B] and [C].

\[
\begin{align*}
A & \leftrightarrow A^{*} \quad \text{(fast equilibrium $K_1$)} \\
A^{*} + B & \leftrightarrow AB^{*} \quad \text{(fast equilibrium $K_2$)} \\
AB^{*} + C & \rightarrow ABC^{\dagger} \quad \text{(slow, $k_3$)} \\
ABC^{\dagger} & \rightarrow AB^{*} + C \quad \text{(slow, $k_{-3}$)} \\
C + ABC^{\dagger} & \rightarrow P + A \quad \text{(slow, $k_p$)}
\end{align*}
\]

In addition, an inhibitor step slows the reaction down by reacting $ABC^{\dagger}$ with $AB^{*}$ occasionally.

\[
ABC^{\dagger} + AB^{*} \rightarrow A^{*} + 2B + C \quad \text{(slow, $k_d$)}
\]

Assume that $ABC^{\dagger}$ is a steady state intermediate while $A^{*}$ and $AB^{*}$ are equilibrated transition states. Write the net reaction and state which species are acting as catalysts for this reaction. Note the inhibitor reaction merely slows down the net reaction but does not reverse it or change the stoichiometry. This is the sort of simplified mechanism which can describe atmospheric chemical reactions.