1. (6 pts) Given the following data at 25°C:

\[
\begin{align*}
2 \text{O}_3 (g) & \rightarrow 3 \text{O}_2 (g) \quad \Delta H^\circ = -427 \text{ kJ} \\
\text{O}_2 (g) & \rightarrow 2 \text{O} (g) \quad \Delta H^\circ = 495 \text{ kJ} \\
\text{NO} (g) + \text{O}_3 (g) & \rightarrow \text{NO}_2 (g) + \text{O}_2 (g) \quad \Delta H^\circ = -199 \text{ kJ}
\end{align*}
\]

Calculate $\Delta H^\circ$ for the following reaction at 25°C:

\[\text{NO} (g) + \text{O} (g) \rightarrow \text{NO}_2 (g)\]

2. (12 pts) Write the reactions that correspond to the following enthalpy changes:

a) $\Delta H^\circ_f$ for solid aluminum oxide.

b) The standard enthalpy of neutralization of aqueous sodium hydroxide and hydrochloric acid.

c) $\Delta H^\circ_f$ for gaseous vinyl chloride, $\text{C}_2\text{H}_3\text{Cl}$.

d) The enthalpy of solution of solid ammonium bromide.

3. (10 pts) Using the following data:

\[
\begin{array}{ccc}
\text{N}_2\text{O}_5 (g) & \Delta H^\circ_f (\text{kJ/mol}) & S^\circ (\text{J K}^{-1} \text{mol}^{-1}) \\
\hline
\text{N}_2\text{O}_5 (g) & 11.29 & 355.3 \\
\text{NO}_2 (g) & 33.15 & 239.9 \\
\text{O}_2 (g) & 0 & 204.8
\end{array}
\]

Above what temperature is the following reaction spontaneous? 

\[2 \text{N}_2\text{O}_5 (g) \rightarrow 4 \text{NO}_2 (g) + \text{O}_2 (g).\]
4. A sample of pure solid naphthalene (C_{10}H_8) weighing 0.6410 g is burned completely with oxygen to produce CO_2 (g) and H_2O (l) in a constant volume calorimeter at 25°C. The amount of heat released is measured to be 25.79 kJ.
   a) (4 pts) Write and balance the equation for the combustion reaction.
   
   b) (4 pts) Calculate the standard change in internal energy, ΔE°, for the combustion of 1.00 mol naphthalene to produce CO_2 (g) and H_2O (l).
   
   c) (4 pts) Calculate the standard change in enthalpy, ΔH°, for the combustion of 1.00 mol naphthalene to produce CO_2 (g) and H_2O (l).

5. (6 pts) Write the electronic configuration and indicate the number of unpaired electrons for each of the following species.

<table>
<thead>
<tr>
<th>electronic configuration</th>
<th>number of unpaired electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Mn</td>
<td></td>
</tr>
<tr>
<td>b) P</td>
<td></td>
</tr>
<tr>
<td>c) N^–</td>
<td></td>
</tr>
</tbody>
</table>

6. (4 pts) The following electron configuration corresponds to an excited state of an atom. Identify the atom and write the ground-state electron configuration.

   [Ar]4s^23d^54p^6

   atom: ground-state electron configuration:

7. a) (6 pts) Draw the Lewis structures for each of the following compounds. Nitrogen is the central atom in both NO_2^– and NO_3^–.

   NO^+          NO_2^–         NO_3^–

   b) (2 pts) Which one of the following has the shortest NO bond length? Circle the correct answer.

   NO^+          NO_2^–         NO_3^–

   c) (2 pts) Which one of the following has the longest NO bond length? Circle the correct answer.

   NO^+          NO_2^–         NO_3^–

8. (8 pts) Use the Bohr model to calculate the energy (in kJ/mol) required to remove the electron in ground state Li^{2+}.
9. (16 pts) Circle the formula that best fits each of the following descriptions:

a) smallest atomic radius  
   Na  Si  S  Al

b) largest ionic radius  
   Na$^+$  O$^{2-}$  Mg$^{2+}$  F$^-$

c) least polar bond  
   C – N  C – O  O – H

d) longest bond length  
   HCl  HF  HI  HBr

e) greatest electronegativity  
   Al  C  Na  N

f) smallest first ionization energy  
   K  Na  Mg

g) greater entropy  
   1.0 mol N$_2$ (g) at 0.01 atm, 25°C  1.0 mol N$_2$ (g) at 1.0 atm, 25°C

h) greater entropy  
   1.0 mol H$_2$ (g) at 1.0 atm, 25°C  1.0 mol H$_2$O (g) at 1.0 atm, 25°C

10. (6 pts) For each of the following molecules, write the Lewis structure, predict the molecular geometry, and indicate the direction of the net dipole.

<table>
<thead>
<tr>
<th>Lewis structure</th>
<th>molecular geometry</th>
<th>polarity</th>
</tr>
</thead>
</table>

On this year’s final you will only need to draw the Lewis structure.

We will cover molecular geometry and polarity next quarter.

You do need to be able to identify polar bonds in molecules.

a) PO$_3^{3-}$

b) SeF$_2$

11. (2 pts) If an endothermic process occurs spontaneously at constant T and P, then the following must be true:

   a) $\Delta S > 0$  
   b) $\Delta G = 0$  
   c) $\Delta H < 0$  
   d) $\Delta S < 0$

12. (2 pts) For any system at equilibrium at constant T and P, the following must be true:

   a) $\Delta H = \Delta S$  
   b) $\Delta H = T \Delta S$  
   c) $\Delta H = -T \Delta S$  
   d) $\Delta G = T \Delta S$

13. (6 pts) What is the oxidation state (number) for

a) C in CaCO$_3$  

b) O in H$_2$O$_2$  

c) P in HPO$_4^{2-}$
14. (4 pts) Indicate which of the following reactions is an oxidation-reduction reaction. Circle yes or no for each reaction.

a) \( \text{C}_2\text{H}_4 (g) + 3\text{O}_2 (g) \rightarrow 2\text{CO}_2 (g) + 2\text{H}_2\text{O} (l) \) Yes No

b) \( \text{CO}_2 + 2\text{LiOH} \rightarrow \text{Li}_2\text{CO}_3 + \text{H}_2\text{O} \) Yes No

c) \( \text{FeCl}_2 + 2\text{NaOH} \rightarrow \text{Fe(OH)}_2 + 2\text{NaCl} \) Yes No

d) \( \text{H}_2 (g) + 2\text{CO} (g) \rightarrow \text{H}_2\text{O}_2 (l) + 2\text{C}(s) \) Yes No

15. (10 pts) An ice cube weighing 36.0 g at a temperature of –10°C is placed in 360 g of water at a temperature of 20°C. Calculate the final temperature (after thermal equilibrium is reached) assuming no heat loss to the surroundings. The enthalpy of fusion of ice is \( \Delta H_{\text{fus}} = 6.0 \text{ kJ/mol} \), the molar heat capacity of ice is \( c_p = 38 \text{ J K}^{-1} \text{mol}^{-1} \), and for water \( c_p = 75 \text{ J K}^{-1} \text{mol}^{-1} \).

16. Answer the following question using the data given below:

<table>
<thead>
<tr>
<th>Half Reaction</th>
<th>( \mathcal{E}^0 ) (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{Au}^{3+} + 3 \text{e}^- \rightarrow \text{Au} (s) )</td>
<td>1.50</td>
</tr>
<tr>
<td>( \text{Ag}^+ + \text{e}^- \rightarrow \text{Ag} (s) )</td>
<td>0.80</td>
</tr>
</tbody>
</table>

(8 pts) A galvanic cell is constructed in which an Ag⁺/Ag half-cell is connected to a Au³⁺/Au half-cell. Calculate the cell potential, \( \mathcal{E}_{\text{cell}} \), when the concentrations are: \( [\text{Au}^{3+}] = 1.0 \text{ M}, [\text{Ag}^+] = 0.01 \text{ M} \)

17. (8 pts) Copper is electroplated from a Cu²⁺ solution. How many seconds will it take to deposit 50.0 g of Cu (s) using a current of 20.0 amp?
18. Chlorine reacts with hydrogen sulfide in aqueous solution. Consider the following reaction mechanism:

\[ \text{H}_2\text{S} \rightleftharpoons \text{H}^+ + \text{HS}^- \] (fast equilibrium)

\[ \text{Cl}_2 + \text{HS}^- \rightarrow \text{H}^+ + 2 \text{Cl}^- + \text{S} \] (slow)

a) (2 pts) What is the overall reaction?

b) (2 pts) List the intermediate(s) in the reaction.

c) (8 pts) Derive the rate law to determine the order of reaction with respect to \( \text{H}^+ \)?

19. (8 pts) The half-life of a certain first order decomposition is 20.0 s at 25°C and 1.0 s at 50°C. Calculate the activation energy for this reaction.

20. (10 pts) Calculate the entropy change for a process in which 3.00 mol of liquid water at 0°C are mixed with 1.00 mol of water at 100°C in a perfectly insulated container.

(Assume the molar heat capacity of water is constant at 75.3 J K\(^{-1}\)mol\(^{-1}\)).