Section 1- Concepts and Definitions
(50 % of the total for this Exam, 5 points each)

1. Fill in the blank.

The Four Laws of Thermodynamics, not necessarily in order are:

The __________________ of a perfectly ordered crystal at 0 K is 0.

The _________ of the isolated system increases for a spontaneous process.

If A is in ________________ with B, and B is in ________________ with C, then C is also
in ________________ with A.

The total ______________________ of the universe is constant.

2. Which of the following is (are) an intensive property (es)?

a. mass
b. temperature
c. entropy
d. chemical composition
e. Gibbs energy
f. pressure
g. none of the above
3. When the pressure of an ideal gas is reduced by factor of 4 and the absolute temperature is increased by factor of 4 its volume is:
   a. constant
   b. increased 4-fold
   c. increased 16-fold
   d. decreased 4-fold
   e. decreased 16-fold
   f. none of the above

4. On the figure below, label the isobar, isotherm and isochore.

   ![Diagram](image)

   T = isotherm; P = isobar. V = isochore.
5. Use the phase diagram for methanol below to answer the questions below.

![Phase Diagram for Methanol](image)

a. If the pressure of the system is fixed at a pressure of 800 psia, raising the temperature from 150 °C to 250 °C would result in a transition from ____ to _____.

b. At 423 K, the liquid phase of methanol is stable down to a pressure of about __________ psia.

c. If the system is at supercritical point at T₀ and P₀ as shown, by decreasing temperature the liquid phase can be obtained.

6. For the reversible chemical reaction involving gases A and B:

\[ 2A \rightleftharpoons B \]

use the Le Chatelier principle to decide the following: when the pressure of the whole system is decreased from 2 atm to 1 atm, the amount of compound B present in equilibrium will:

a. Decrease;

b. Increase;

c. Remain constant.
7. For the dilute solutions, provide up to four examples of physical phenomena observed experimentally that represent the colligative properties of the solvent or the solute. Indicate the properties of which component of the solution, e.g. of solvent or solute are being changed.

8. For chemical reaction taking place in the electrochemical device, assign the correct symbols for $\Delta G_r$ and electromotive force $E$ in the Figure below.

Possible symbols: $> \quad < \quad = \quad \geq \quad \leq \quad \neq \quad \approx$

Example: $E = 0$. 

![Gibbs energy diagram](image-url)
9. The rate of the reaction

\[ A + 2B \rightarrow 2C + 3D \]

was reported as 1.0 mol dm\(^{-3}\) s\(^{-1}\). Determine the rates of formation and consumption of reactants and products.

10. The rate law for the reaction:

\[ A + 2B \rightarrow 3C + D \]

was found to be \( v = k [A][B] \). What are the units of \( k \)? Express the rate law in terms of the rates of formation and consumption of

a) A;

b) C.
Section 2- Problems (50 % of the total for this Exam, 10 points each)

1. The boiling point of a substance is the temperature at which the equilibrium is achieved between its liquid and vapour phases.

\[ C_6H_6 (l) \rightleftharpoons C_6H_6 (v) \]

Calculate the boiling point of benzene, if \( \Delta H^\circ = 30.8 \text{ kJ/mol} \) and \( \Delta S^\circ = 87.17 \text{ J K}^{-1} \text{ mol}^{-1} \) for this process.
2. Show how to derive the Maxwell relationship for Gibbs energy.
3. At 25 °C, the density of a 50 % by weight solution of ethanol in water is 0.914 gram per cm$^3$. Given the partial molar volume of water in this solution is 17.4 cm$^3$/mol, calculate the partial molar volume of the ethanol.
4. Using the following reaction and thermodynamic data at 25 °C as below, calculate the value of constant K of thermodynamic equilibrium at 25 °C and 85 °C.

\[ 2\text{H}_2\text{O}_2 \text{(aq)} \rightleftharpoons 2\text{H}_2\text{O} \text{(l)} + \text{O}_2 \text{(g)} \]

<table>
<thead>
<tr>
<th>Compound</th>
<th>( \Delta_f^\circ \text{H}, \text{kJ/mol} )</th>
<th>( \Delta_f^\circ \text{G}, \text{kJ/mol} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{H}_2\text{O}_2 \text{(aq)} )</td>
<td>-191.17</td>
<td>-120.35</td>
</tr>
<tr>
<td>( \text{H}_2\text{O} \text{(l)} )</td>
<td>-285.83</td>
<td>-237.13</td>
</tr>
<tr>
<td>( \text{O}_2 \text{(g)} )</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
5. At 518°C, the rate of decomposition of a sample of gaseous acetaldehyde, initially at a pressure of 363 Torr, was 1.07 Torr s$^{-1}$ when 5.0 % had reacted and 0.76 Torr s$^{-1}$ when 20.0 % had reacted. Determine the order of the reaction.