1. (20 pts) Define or explain the following:
   a. Leveling effect (3)
   b. Buffer capacity (3)
   c. The 2nd law of thermodynamics (3)
   d. Gibbs free energy (3)
   e. The difference between a UV-Vis spectrometer and a fluorescence spectrometer (8)

2. (15 pts) Tris(hydroxymethyl)aminomethane, (HOCH₂)_3CNH₂, (TRIS or THAM) has a pK close to physiological pH (pKₐ = 8.08 for the conjugate acid). A biochemist wants to prepare one liter of TRIS buffer at pH 7.40 with an analytical concentration of total TRIS to be 0.1 M and ionic strength 0.2.
   a. How many grams of TRIS, NaOH and NaCl does he need? (10)
   b. How will he prepare the solution? (5)

3. (15 pts) Consider the titration of a 50.00 mL, 0.1 M solution of dimethyl amine (pKₐ = 3.22) by a 0.1 M HCl standard solution.
   a. Calculate the pH when 25.00 mL of HCl is added. (6)
   b. Calculate the pH when 50.00 mL of HCl is added. (6)
   c. If four indicators are available:
      Indicators          Color Change Range, pH
      Methyl orange       3.1 - 4.4
      Methyl red          4.2 - 6.3
      Phenol red          6.8 - 8.4
      Phenolphthalein     8.3 - 10.0
      Which one is the best for the above titration? (3)

4. (15 pts)
   a. Calculate the equilibrium concentrations of all species in a 0.01 M solution of the dipeptide glycglycine at pH 4.00. pKₐ1 and pKₐ2 are 2.35 and 9.60, respectively. (10)
   b. What is the pI of the above solution? (5)
5. (25 pts) An enzymatic reaction can be represented as

\[ E + S \rightleftharpoons ES \rightleftharpoons E + P \]

The reverse reaction between E and P to form ES is often slow enough to be neglected,

a. Show that the steady state concentration [ES] is

\[ [ES] = \frac{k_1[E][S]}{(k_1 + k_2)} \]

and the reaction rate, \( v \), can be expressed as

\[ v = k_2[E]_0 \left(1 + \frac{k_1 + k_2}{k_1[S]}\right) \] where \([E]_0\) is the initial concentration of the enzyme. (5)

b. Defining the Michaelis constant, \( K_m = \frac{1}{k_1 + k_2} \), show that

\[ v = k_2[E]_0[S]/(K_m + [S]) \] (5)

c. In practical application, it is best to transform the equation b into a linear form, show that the Lineweaver-Burk equation

\[ 1/v = \frac{K_m}{V}[1/[S]] - [1/V] \] where the maximum rate \( V = k_2[E]_0 \) (5)

d. The hydrolysis of sucrose by the enzyme invertase was followed by measuring the initial rate of change in polarimeter readings at various initial concentrations of sucrose:

<table>
<thead>
<tr>
<th>Sucrose (mol.dm⁻¹)</th>
<th>0.0292</th>
<th>0.0584</th>
<th>0.0876</th>
<th>0.117</th>
<th>0.146</th>
<th>0.175</th>
<th>0.234</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial rate</td>
<td>0.0182</td>
<td>0.265</td>
<td>0.311</td>
<td>0.330</td>
<td>0.349</td>
<td>0.372</td>
<td>0.371</td>
</tr>
<tr>
<td>Initial rate (2M urea)</td>
<td>0.083</td>
<td>0.111</td>
<td>0.154</td>
<td>0.182</td>
<td>0.186</td>
<td>0.192</td>
<td>0.188</td>
</tr>
</tbody>
</table>

By means of a Lineweaver-Burk plot, estimate the Michaelis constant \( K_m \) for the enzyme-substrate complex. (10)

6. (10 pts) Which of the following is true for the reaction \( H_2O(g) \rightleftharpoons H_2O(l) \) at 100°C and 1 atm pressure? (a) \( \Delta H = 0 \) (b) \( \Delta S = 0 \) (c) \( \Delta H = \Delta U \) (d) \( \Delta H = T \Delta S \) (e) \( \Delta H = \Delta G \). Show your reason.