1. One mole of ideal gas at 300 K is expanded reversibly and isothermally from a pressure of 10 bar to 1 bar. What are the values of w, q, ΔU, ΔH, ΔS, ΔA, and ΔG? (15%)

2. Show that the freezing of a mole of supercooled water at $-10\,°C$ is a spontaneous process.

   $H_2O(l, -10\,°C) = H_2O(s, -10\,°C)$

   For the crystallization of liquid water at $0\,°C$, $\Delta H° = -6004\ Jmol^{-1}$. The heat capacity of water may be taken to be $75.3\ JK^{-1}mol^{-1}$, and that of ice may be taken to be $36.8\ JK^{-1}mol^{-1}$ over this range. (15%)

3. The following thermodynamic data apply to the complete oxidation of butane at $25°C$.
   $$C_4H_{10\,(g)} + 6.5\ O_{2\,(g)} \rightarrow 4\ CO_{2\,(g)} + 5\ H_2O_{(l)}$$

   Given: $\Delta H° = -2877\ kJ\,mol^{-1}$ $\Delta S° = -432.7\ JK^{-1}mol^{-1}$

   (a) When one mole of methane is oxidized completely in a Carnot engine that operates between $100\,°C$ and $25\,°C$, what is the maximum work that could be produced? (7%)
   (b) Suppose that a completely efficient fuel cell could be set up utilizing this reaction. Calculate the electromotive force and the maximum electrical work. (8%)

4. Construct the phase diagram for benzene in the vicinity of its triple point (36 Torr, $5.50\,°C$) using the following data:

   $\Delta_{fus}H° = 10.6\ kJmol^{-1}$, $\Delta_{vap}H° = 30.8\ kJmol^{-1}$,

   $\rho(s) = 0.91\ g\,cm^{-3}$, $\rho(l) = 0.899\ g\,cm^{-3}$.   (10%)

5. Suppose it is known that ozone (O_3) adsorbs on a particular surface in accord with a Langmuir isotherm. How could you use the pressure dependence of the fractional coverage to distinguish between adsorption without dissociation and with dissociation into $O + O_2$? (15%)

6. For two simultaneous (parallel) reactions

$$A \xrightarrow{\;k_1\;} Y$$

$$A \xrightarrow{\;k_2\;} Z, \quad \text{with } [A]=[A]_0 \text{, and } [Y]=[Z]=0 \quad \text{at} \quad t=0$$
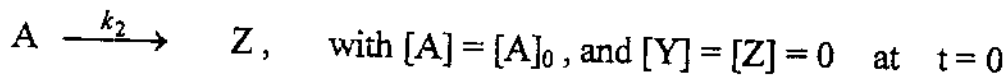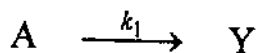
(a) Show that $[Y]/[Z]=k_1/k_2$. (7%)
(b) Define that the selectivity $S=[Y]/[Z]$, how will be the effect of increasing temperature on the selectivity if $E_{a1}>E_{a2}$? (8%)

7. The rate of an enzyme-catalyzed reaction in which a substrate S is converted into products P is found to depend on the concentration of the enzyme E even though the enzyme undergoes no net change. The proposed mechanism is

$$E+S \underset{k_2}{\overset{k_1}{\rightleftharpoons}} ES \xrightarrow{\;k_3\;} P+E \qquad\qquad , [E]=[E]_0 \quad \text{at} \quad t=0$$
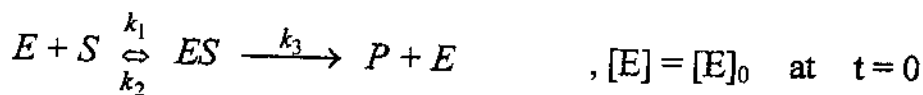
Show that the rate of formation of product is

$$\frac{d[P]}{dt}=\frac{k_3[E]_0[S]}{k_M+[S]}$$

where the Michaelis constant, k_M is $\quad k_M=\dfrac{k_2+k_3}{k_1}$. (15%)