國立清華大學 107 學年度碩士班考試入學試題

系所班組別：生醫工程與環境科學系乙組 (環境與分子科學組)

考試科目（代碼）：物理化學 (2602)

Fundamental constants

$c = 3.0\times10^{8}$ m/s, $e = 1.6\times10^{-19}$ C, $N_A = 6.02\times10^{23}$ mol^{-1}, $R = 0.082$ atm L/(K mol) = 8.314 J/(K mol), $k = 1.38\times10^{-23}$ J/K, $h = 6.626\times10^{-34}$ Js, $m_e = 9.11\times10^{-31}$ kg

1. Electron microscopes operate on the fact that electrons act as waves. A typical electron kinetic energy is 100 keV (1 eV = 1.602×10^{-19} J). What is the wavelength of such an electron? (Ignore relativistic effects.) (20%)

2. To calculate the work required to lower the temperature of an object, we need to consider how the coefficient of performance changes with the temperature of the object. (a) Find an expression for the work of cooling an object from T_i to T_f when the refrigerator is in a room at a temperature T_h. Hint: Write dw = dq/c(T) where the coefficient of performance, $c(T) = \dfrac{T}{T_h - T}$, the energy transferred as heat, $dq = C_p dT$, and integrate the resulting expression. Assume that the heat capacity is independent of temperature in the range of interest. (b) Use the result in part (a) to calculate the work needed to freeze 250 g of water in a refrigerator at 293 K. How long will it take when the refrigerator operates at 100 W? The heat capacity and the heat of fusion for water is $C_p = 4.184$ J/Kg and $\Delta_{fus}H = 334$ J/g, respectively. (20%)

3. Calculate the boiling temperature of water at an altitude of 8900 m, the top of the world (Mount Everest). Assume that the atmosphere is at equilibrium at a temperature of 20 °C and the use of the Boltzmann distribution to estimate the barometric pressure. Air is a single gas with molar mass 0.028 kg/mol and the molar enthalpy change of vaporization of water is equal to 40.66 kJ/mol. State any other assumptions. (20%)

國立清華大學 107 學年度碩士班考試入學試題

系所班組別：生醫工程與環境科學系乙組 (環境與分子科學組)

考試科目（代碼）：物理化學 (2602)

4. Suppose that the enzyme E and substrate S combine to form a complex ES, which then dissociates into product P and free enzyme E. The product rate follows Michaelis-Menten form:

$$v = \frac{dp}{dt} = \frac{V_{max}[S]}{K_m + [S]}$$

In noncompetitive inhibition, the inhibitor I binds to a site other than the active site of the enzyme, so inhibitor I and substrate S can simultaneously bind to the enzyme, forming the ternary complex designated EIS. Binding of either inhibitor or substrate does not influence the affinity of either species to complex with the enzyme.

(a) Give a schematic representation of the model for the noncompetitive inhibition.

(b) If the dissociation constant of EI is K_I, please derive a rate expression for P formation with V_{max}, [S], K_m, [I], and K_I, by assuming quasi-steady state for [ES] and for [EI]. Draw a plot with 1/v against 1/[S] by varying [I]. (20%)

5. Compute the freezing point temperature versus composition curve based on mole fraction for an ortho-chloronitrobenzene–para-chloronitrobenzene mixture. The physical properties for this system are given in Table 1. Calculate and mark the eutectic point. Sketch the liquid-solid phase diagram for this system and state what substances exist in each region. Assume negligible solid-solid solubility. (20%)

Table 1. Thermodynamic data

	o-chloronitrobenzene	p-chloronitrobenzene
Molecular weight (g/mol)	157.55	157.55
Density (g/mL)	1.368	1.52
Heat of fusion (kJ/mol)	19	20.8
Normal melting point (°C)	32.5	83.5