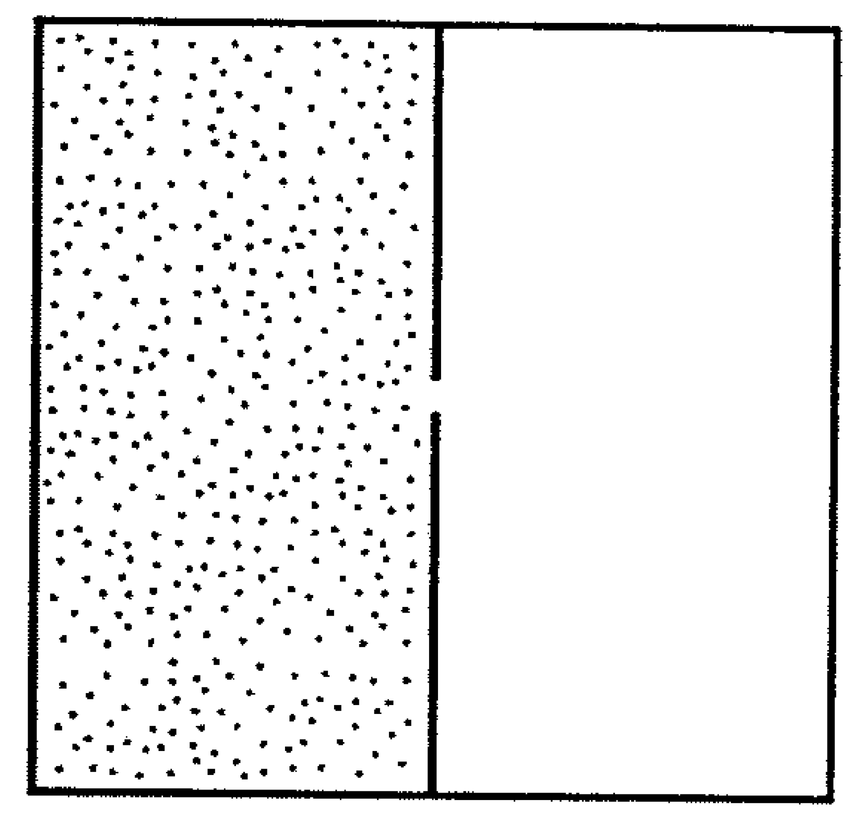
國立清華大學 102 學年度碩士班考試入學試題

系所班組別：生命科學院乙組(0505)、生命科學院丙組(0506)、醫學生物科技學程(0507)

考試科目（代碼）：物理化學(0503、0603、0707)

　　*請在【答案卷、卡】作答

1. A box with rigid adiabatic walls is separated into two equal volume compartments by a membrane. The left compartment contains an ideal gas at temperature T, and the right compartment is empty. A small hole is punched through the membrane, allowing the gas to fill up the whole box, and the system comes to equilibrium. (10%)



(a) Show that this process is irreversible.

(b) What is the final temperature of the gas?

2. The heat required to melt ice at 1 atm and 0°C is 333 J/g. When 1 mole of ice is melted under these conditions, calculate (a) the work done, (b) the change in internal energy and (c) the change in entropy. (The density of ice is 0.92 g/cm^3; the density of water is 1 g/cm^3) (15%)

3. Give the definition of entropy in statistical physics. (5%)

4. In protein chemistry, we usually encounter a situation to define protein oligomerization state in solution. Please descript 3 different methods to differentiate the presence of protein monomer, dimer and tetarmer in solution. Please also describe the basic ideas of the methods. (10%)

5. The molar extinction coefficient ε of benzene equals 100 M^{-1}cm^{-1} at 260 nm. Assume that this number is independent of solvent and temperature.

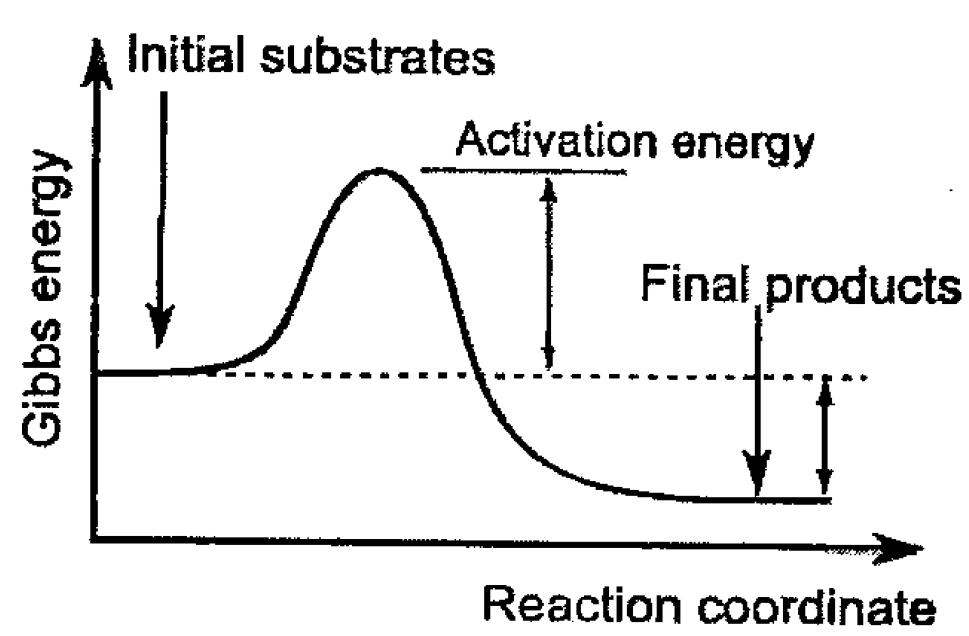
(a) What concentration would give an absorbance of 0.5 in a 1-cm cell at 260 nm. (5%)

(b) What concentration would 10% of 260 nm light to be transmitted through a 1-cm cell? (5%)

(Hint: the Beer-Lambert law $A = -\log I/I_0 = \varepsilon\, C\, L$. I: intensity, A: absorbance, C: concentration, L: pathlength)

6. To study protein denaturation is an important issue in protein chemistry. Please explain how we can use the following three different methods to study protein denaturation: (a) circular dichroism (CD), (b) florescence and (c) nuclear magnetic resonance spectroscopy (NMR). (15%)
(Hint: please start your answer form describing the difference of spectra of folded and unfolded protein.)

7. Enzymes accelerate reactions that have a substantial activation energy. The plot below shows the energy surface for a reaction without enzyme. Please draw a curve indicating how the energy surface changes when an enzyme is added to the reaction. (5 %).



8. Consider electrons in a hydrogen atom in the energy state n=3:

(a) How many degenerated states are there? List all possible values of the quantum numbers l and m_l. (5 %)

(b) Assuming an electron is originally at 3s (n=3, l=0, m_l=0) orbital and then make a transition to the n=4 state by absorbing a photon. Considering the conservation of orbital angular momentum, which orbital (4s, 4p, 4d, etc) the electron will stay? Why? (5 %)

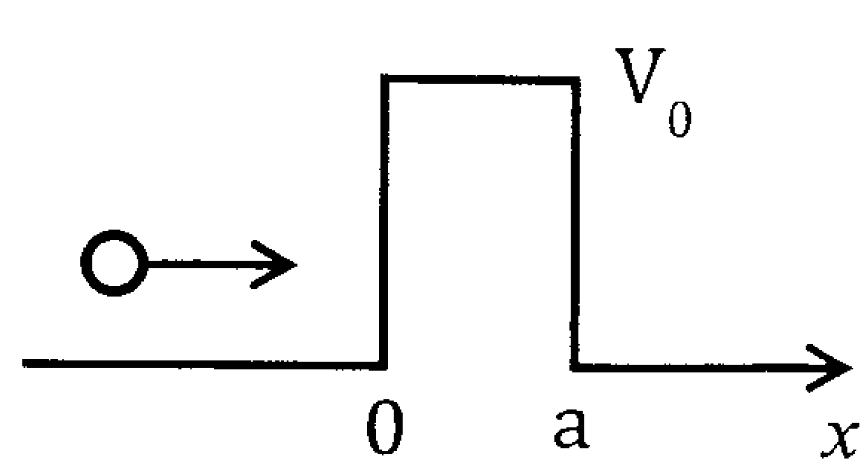
9. The probability of a particle occupying a state i with energy E_i is given by the Boltzmann distribution:

$$P_i = \frac{e^{-E_i/k_B T}}{\sum_i e^{-E_i/k_B T}}$$

(a) Consider free electrons in the presence of a magnetic field. The energy levels split for the two spin states and the difference in the energy between the states is 4.14×10^{-25} J. Calculate the population ratio of electrons between the two energy states at T=300K. $K_B = 1.38\times10^{-23}$ J/K. (3 %)

(b) In the same system as in A, if now we cool the system down to $T=3\times10^{-3}$ K, what is the population ratio of electrons between the two energy states? (3 %)

10. Consider the quantum tunneling of a one-dimensional particle encountering an energy wall as shown below. The particle carries a mass m and an energy E, which is smaller than V_0.



(a) Write down the time-independent Schrödinger's equation for the three regions: $x < 0$, $0 \le x \le a$, and $x > a$. (6%)

(b) The solution to the Schrödinger's equation in the region x < 0 is

$\psi(x) = Ae^{ik_I x} + Be^{-ik_I x}$ where A and B are arbitrary constants and $k_I = \frac{\sqrt{2mE}}{\hbar}$.

Similarly, please write down the solutions for the regions $0 \le x \le a$, and $x > a$. You don't need to solve for the arbitrary constants. (4 %)

(c) Explain what the quantum tunneling effect is and give one example (natural phenomena or technology application). (4 %)