國立清華大學 104 學年度碩士班考試入學試題

系所班組別：生命科學院乙組、丙組

考試科目（代碼）：物理化學(0503、0603)

1. (12%) A bimetallic strip of length L and total thickness D (each metal has thickness D/2) is straight at temperature T. Assume that the coefficients of linear expansion of the two metals are $\alpha 1$ and $\alpha 2$, respectively ($\alpha 1 > \alpha 2$). What is the radius of curvature of the strip when temperature is raised by ΔT? Note that D is much less than the radius.

2. (10%) Two moles of ideal gas are allowed to expand from volume V to 2V at (a) constant pressure, (b) constant temperature. Calculate the work done and the heat absorbed by the system in each case. Assume the initial temperature is T_o.

3. (12%) Complete the following equations: (a) $\triangle U = q +$ ___; (b) $H =$ ___ $+ PV$; (c) $\triangle G = \triangle H - T\triangle$____; (d) $K_{eq} = e$ __/RT; (e) $(\partial G/\partial P)T =$ ___; (f) $(\partial G/\partial T)P =$ ___.

4. (8%) Consider an enzyme reaction $E + S \underset{k_{b1}}{\overset{k_{f1}}{\leftrightarrow}} ES \xrightarrow{k_{f2}} E + P$ where S is the enzyme, E is the substrate, ES is the enzyme-substrate complex and P is the product. The reaction rate can be described by the Michaelis-Menten equation

$$V_0 = \frac{V_{\max}[S]}{K_M + [S]}$$

where V_0 is the initial rate, $V_{\max}$ is the maximum rate and $K_M (= \frac{k_{b1} + k_{f2}}{k_{f1}})$ is the Michaelis constant. (a) Please show how that the question can be transformed into a linear relationship between $1/V_0$ and $1/[S]$ (5%). (b) Please draw a double-reciprocal plot for the linearized equation and show how K_M can be determined in the plot (3%).

5. (6%) The probability of a particle occupying a state i with energy E_i is given by the Boltzmann distribution:

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

Consider a free particle in the presence of a magnetic field which splits the energy of the particle into two states. If an observer found the population ratio of the electrons between the high and low energy states to be 0.368, what is the energy difference between the two states? T=100K. $K_B = 1.38\text{x}10^{-23}$ J/K. $e^{-1.0} = 0.368$.

6. (12%) What is quantum tunneling? Please give one example (a naturally occurred phenomenon or a device made use of quantum tunneling).

7. (10%) An electron in a hydrogen atom is in a state described by the wave function

$\Psi = \sqrt{\frac{1}{\pi a_0^3}} e^{-r/a_0}$, where a_0 (=0.5292 x 10^{-10} m) is the Bohr radius.

A. The quantum number n of this state is equal to 1. What are the values of the other two quantum numbers l and m_l?

B. The probability of finding the electron at a certain radius is given by $\Psi^*\Psi(4\pi r^2)dr$. Show that the most probable radial position of the electron is its Bohr radius.

8. (8%) Please calculate frequency of the wavelength of 300 nm, if we consider the velocity of light is approximately 3 x 10^8 m s^{-1}. Please convert the frequency to energy by Planck's equation. $h = 6.626 \text{ x } 10^{-34}$ J s.

9. (15%) A double-stranded oligonucleotide (duplex D) "melts" to two single strands, S and R when temperature increases.

$$D \Leftrightarrow S + R$$

A duplex of 100 μM is melted when temperature increases. At 10 °C, the solution contains double-stranded DNA and at 60 °C, the solution only contains single strands, S and R. The absorbance at 260 nm increases when the population of single strand gets higher. Assume that the molar extinction coefficient ε of D, S and R are independent of temperature. The temperature-dependent absorbance (measured in 1 cm path length) is shown in the table.

Temp (°C)	10	15	20	25	30	35	40	45	50	55	60
A_{260}	0.95	0.96	0.97	0.98	1.02	1.08	1.14	1.16	1.19	1.20	1.21

(a) Use Beer-Lambert law ($A_{260} = \varepsilon cl$) to calculate the extinction coefficient ε (M^{-1} cm^{-1}) of double-stranded DNA, D, by considering the condition of 10 °C.

(b) If we assume S and R are with the same ε, please calculate ε of S and R by considering the condition of 60 °C.

(c) Evaluate the melting temperature of the duplex D that melting temperature is defined as the temperature at which the duplex is half-melted.

10. (7%) Please explain how to use FPLC gel filtration chromatography and SDS PAGE to determine protein size.