國立臺灣大學 107 學年度碩士班招生考試試題

1.

(a) (5 marks) Given that the density of pure water is 1.0 g/cm^3 and assume that each water molecule is a cube. Calculate the average distance between two neighboring water molecules in the unit of angstrom.

(b) (5 marks) If there are a total of 4.00×10^2 protein molecules confined in a spherical liposome which has a diameter of 250.0 nm, what is the concentration of the protein inside the liposome in the unit of μM?

(c) (5 marks) Calculate the mole fraction, molality, and molarity of methanol in water when we mix 20.0 mL of methanol and 80.0 mL of water. You can assume the conditions of ideal mixture in your calculations. [Density of methanol is 792 mg/mL]

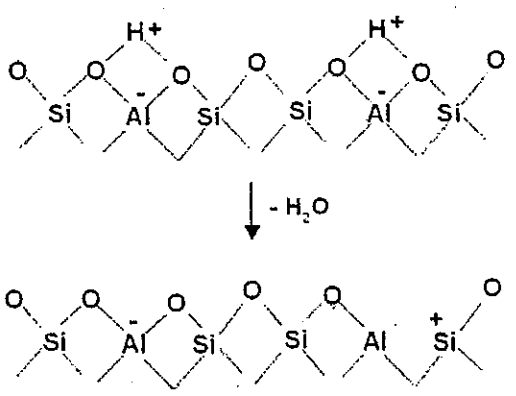
2.

(a) (5 marks) Explain why the sum of pK_a and pK_b of a weak acid and its conjugate pair is equal to 14 at room temperature.

(b) (5 marks) It has been reported that pK_a = 14 and pK_b = 14 for pure water at room temperature. Explain why their sum is not equal to 14.

(c) (5 marks) At a temperature of 50 °C, is the sum of pK_a and pK_b of a weak acid larger than or smaller than 14? Explain why.

(d) (5 marks) The following chemical transformation is important in the preparation of silica catalysts. Copy the diagram of [A] and [B] in the answer book and use arrows to mark the Lewis and Brønsted acid sites.



[A]

[B]

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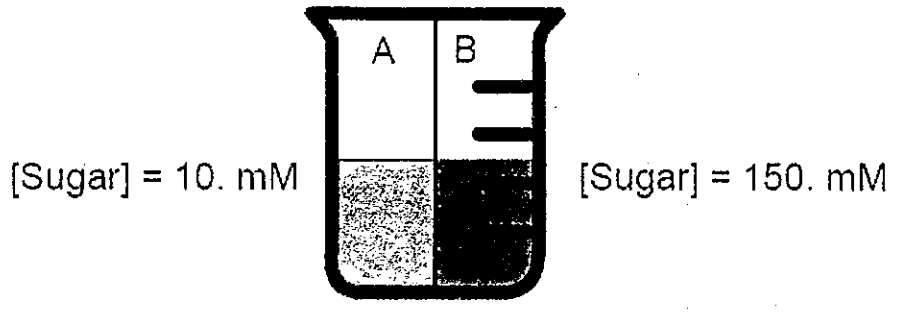
3. (15 marks) Calculate the change in Gibbs free energy for the diffusion of sugar molecules from B to A through the membrane at room temperature, under the concentration gradient shown in the figure. ($R = 8.314\ JK^{-1}mol^{-1}$).



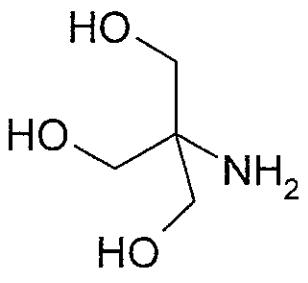
4.

(a) (5 marks) Consider a mineral salt known as octacalcium phosphate (OCP), $Ca_8(PO_4)_4(HPO_4)_2{\cdot}5H_2O$. If some of the "$PO_4$" ions are substituted by carbonate ions, will the amount of Ca^{2+} ions per OCP unit increase, decrease, or remain the same? Explain why.

(b) (5 marks) Consider the substituted OCP compound with a formula of $Ca_y(PO_4)_{4-x}(HPO_4)_2(CO_3)_x{\cdot}5H_2O$. Experimentally it is found that the ratio of Ca/P = 1.40. Determine x and y.

5. (20 marks)

Tris is widely used as a buffer in biology and it has the following formula.



The pK_a value of Tris is 8.07 at room temperature. Given a solution of 0.1 M Tris, describe how you can prepare a 500 mL of 0.050 M Tris buffer solution at pH 7.40? [Assume you have access to 1.0 M HCl, 1.0 M NaOH, and distilled water]

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6.

As a crude approximation, objects such as stars are regarded as black bodies in astronomy. Accordingly, the radiation emitted by a black body per unit area is given by the following equation:

$$\Phi = \sigma T^4$$

where σ is the Stefan-Boltzmann constant (5.67×10^{-8} W m^{-2} K^{-4}).

On the other hand, it has been reported that the solar radiation flux intercepted by Earth is F_S and that the Earth only adsorbs the fraction $(1 - A)$ of F_S, where $F_S = 1370$ W/m^2 and $A = 0.280$.

(a) (5 marks) To calculate the total energy absorbed by the Earth, we have to multiply the absorbed flux by an area. There are two possible options to calculate the area, viz., the total surface area of the Earth shined by the Sun or the cross-section area of the Earth. Explain which one is more appropriate.

(b) (5 marks) In the absence of atmosphere, calculate the effective temperature of the Earth under equilibrium conditions.

(c) (10 marks) In a simple model of greenhouse effect, a thin layer of greenhouse gas (CO_2, H_2O, etc.) high above the Earth surface would behave as a black body and it will absorb a fraction (f) of the radiation emitted by the Earth surface but not the radiation from the Sun. The thin gas layer has a different temperature from the temperature on the Earth surface (T_E). Calculate the T_E if f is 0.770. State clearly all the assumptions or approximations in your calculation.

You may or may not find the following constants useful:

Avogadro's number = 6.022×10^{23}

Boltzmann constant = 1.380×10^{-23} JK^{-1}

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