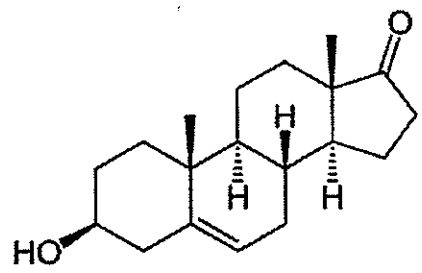
國立臺灣大學 115 學年度碩士班招生考試試題

1. (10 marks) A certain first-order reaction has a rate constant of $3.20 \times 10^{-2}\ s^{-1}$ at 27.0 °C. What is the value of k at 60.0 °C if the activation energy E_a is equal to 90.0 kJ/mol?

2. （8 marks）Below is the structure of dehydroepiandrosterone (DHEA), a hormone in humans:



For each of the following statements, write down whether it is correct or not. **For the incorrect statements, provide reasons to support your judgment.**

A) DHEA does not contain any CH_3 groups.
B) The carbonyl carbon (C=O) is sp^3 hybridized.
C) The carbon atoms of DHEA are sp^2 and sp^3 hybridized only.
D) The oxygen atoms in DHEA do not have any lone pair electrons.

3. The compound *para*-aminobenzoic acid is commonly listed as PABA on commercial bottles of sunscreen.

(a) (5 marks) Elemental analysis shows that PABA is composed of carbon (61.31%), hydrogen (5.14%), nitrogen (10.21%), and oxygen (23.33%). Find the empirical formula of PABA.

[Molar mass information (g/mol): carbon 12.01, hydrogen 1.01, nitrogen 14.01, oxygen 16.00]

(b) (5 marks) By mass spectrometry, we can show that PABA has a molar mass of 137.14 g mol^{-1}. Deduce the molecular formula of PABA.

(c) (5 marks) By infrared spectroscopy, we can show that PABA has a benzene ring, NH_2, and COOH groups. Write down three different structural formulae possible for PABA.

(d) (5 marks) Describe two experimental methods to determine the correct structural formula for PABA.

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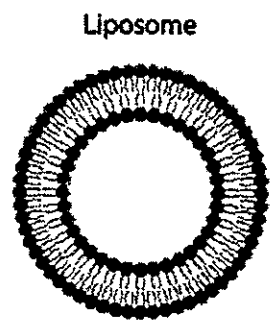
4. (10 marks) Consider a 0.1 M aqueous solution of ammonium acetate ($CH_3COO NH_4$). Without calculating the final pH, list all the equations based on the concentrations of the relevant species for the determination of the pH of this solution. [Hints: you should provide a total of six equations]

5. Liposomes are spherical vesicles composed of one or more phospholipid bilayers that self-assemble in aqueous environments, forming an internal compartment capable of encapsulating both hydrophilic and hydrophobic substances.



(a) (5 marks) Assume that the interior spherical compartment of a liposome has a diameter of 2 μm. What is the volume of the compartment in the unit of nm^3?
(b) (10 marks) If we want to form a shell of $CaCO_3$ of 2-nm thickness covering the interior surface, what is the required number of moles of Ca^{2+} ions? [Assume a density of 2.71 g/cm^3 for $CaCO_3$ solid]
(c) (5 marks) Before the precipitation of $CaCO_3$ inside the liposome in (b), what is the concentration of the Ca^{2+} ions inside the liposome?

6. (10 marks) Given that the density of pure water is 1.0 g/mL, estimate the distance between neighboring water molecules in the unit of angstrom (Å) by explicit calculations. You need to state clearly all the inherent assumptions in your calculations.
[Avogadro's number = 6.022×10^{23}]

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7. To estimate the age of a rock, one can use the decay of ^{238}U into ^{206}Pb. The "gold standard for U-Pb dating is zircon ($ZrSiO_4$). The crystal structure of zircon allows Uranium atoms to substitute for Zirconium, but it chemically rejects Lead atoms during formation.

(a) (5 marks) A typical chemical formula for Uranium-substituted zircon is

$(Zr_{1-x}U_x)SiO_4$

Assume that the Zr and U ions have the same charge, write down their charge.

(b) (5 marks) Occasionally the U ions in a zircon may have higher charge than Zr ions if the rock formed in a very oxygen-rich environment. In this case, what could be the chemical change in the rock?

(c) (5 marks) If $x = 0.001$, calculate the amount of U in ppm unit.
[Uranium: 238.03 g/mol; Zirconium: 91.22 g/mol; Silicon: 28.09 g/mol; Oxygen: 16.00 g/mol]

(d) (7 marks) A zircon was found to have 0.115 mg of ^{206}Pb and 1.000 mg of ^{238}U. Assuming all ^{206}Pb originated from the radioactive decay of ^{238}U and that the half-life of this process is 4.5×10^9 years, estimate the age of the rock.

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