※ 注意：請於試卷上「非選擇題作答區」依序作答，並應註明作答之題號。

1. Name the following compounds in either English common name or English IUPAC systematic name.

(a) CuI (b) CuI_2 (c) LiCl (d) CH_3COOH (e) Na_2CO_3 (f) Al_2O_3

(g) KH_2PO_4 (h) $HClO_4$ (i) HClO (j) CH_3CH_2OH (20%)

2. Citric acid, which can be obtained from lemon juice, has the molecular formula $C_6H_8O_7$. A 0.250 g sample of citric acid dissolved in 25.0 mL of water requires 37.2 mL of 0.105 M NaOH for complete neutralization. How many acidic hydrogens per molecule does citric acid have? (5%)

3. The nitrogen content of organic compounds can be determined by the Dumas method. The compound is first reacted by passage over hot CuO(s):

$$\text{Compound} \xrightarrow[CuO]{hot} N_2(g)+CO_2(g)+H_2O(g)$$

The gaseous products are then passed through a concentrated solution of KOH to remove the CO_2. After passage through the KOH solution, the gas contains N_2 and, meanwhile, is saturated with water vapor. In a given experiment a 0.253 g of a compound produced 31.8 mL of N_2 *saturated with water vapor at 25°C and pressure 726 torr. What* is the mass percent of nitrogen in the compound? (The vapor pressure of water at 25°C is 23.8 torr.) (6%)

4. (a) Consider acid solutions in which the contribution of water to the H^+ concentration is not negligible. The acid equilibrium reaction is

$HA(aq) \rightleftharpoons H^+(aq) + A^{-1}(aq)$ acid dissociation constant: K_a

Derive the exact algebraic equation for $[H^+]$ of this aqueous solution.

(b) From the equation, deduce the quantitative conditions that the contribution of $H^+(aq)$ from water could be neglected *in the solution systems.* (8%)

5. What are the major scientific contributions by the scientists listed below: (20%)

(a) *Max Planck*

(b) Louis de Broglie

(c) Niels Bohr

(d) Werner Heisenberg

(e) Linus Pauling

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6. For hydrogen-like atoms, the wave functions for the 1s and 3s orbitals are

$$\psi(1s)=\frac{1}{\sqrt{\pi}}\left(\frac{Z}{a_o}\right)^{3/2}e^{-\sigma}$$

$$\psi(3s)=\frac{1}{81\sqrt{3\pi}}\left(\frac{Z}{a_o}\right)^{3/2}(27-18\sigma+2\sigma^2)e^{-\sigma/3}$$

in which $\sigma = Zr/a_o$, $a_o = 5.29\times10^{-11}\text{m}$

(a) Determine the radius of the **most probable radial probability** of the 1s state.

(b) Calculate the position of the nodes for the 3s states.

(c) Calculate the relative probability ratio of finding the electron between the 1s and 3s states centered **at the nucleus** (i.e. the origin position).

(d) For the 1s and 3s states, calculate their relative probability ratio of finding the electron in a **shell** located at a radius distance of 300 pm. (12%)

7. The diatomic molecule OH exists in the gas phase. Assume that the molecular orbitals (MOs) of the OH molecule results from the overlap of a $2p_z$ orbital from oxygen and the 1s orbital of hydrogen (the O-H bond lies along the z axis).

(a) Draw pictures of the sigma bonding and antibonding molecular orbitals in OH.

(b) Which of the two MOs obtained in (a) has a greater hydrogen 1s character?

(c) Can the $2p_x$ orbital of oxygen form MOs with the 1s orbital of hydrogen? Explain.

(d) Knowing that only the 2p orbitals of oxygen interact significantly with the 1s orbital of hydrogen, complete the MO energy-level diagram for OH. Place the correct number of electrons in the energy levels.

(e) Estimate the bond order for OH.

(f) Predict whether the bond order of OH^+ is greater than, less than or the same as that of OH. Explain. (12%)

8. (a) For a first order chemical reaction, $A \xrightarrow{k} B$, write down its differential rate law and also its integral solution.

(b)What are the life-time and half-life of this reaction? (8%)

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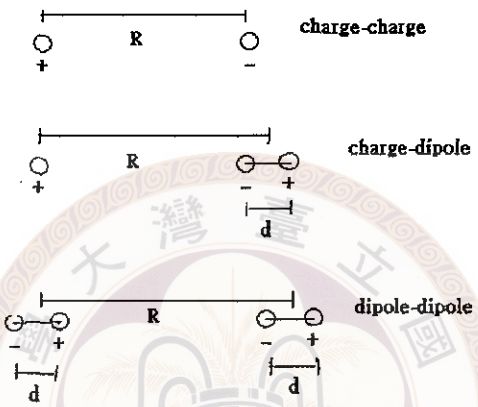
9. The following figure indicates three types of electrostatic interactions. The + sign means a +q charge and the – sign a –q charge. Assuming that the charge separation R is much larger than the dipole charge separation d, derive the interaction potentials for each of these three types of configurations. (Note: the final forms should be expressed in terms of the dipole moment and R for the charge-dipole and dipole-dipole interactions)

(9%)



Some physical constants:

Atomic weights: H = 1.008 C = 12.01 N = 14.01 O = 16.00

R = 1.987 cal/mol-deg = 8.314 J/mol-deg = 0.0821 L atm K^{-1} mol^{-1}

Charge of an electron = 1.60×10^{-19} C

Mass of an electron = 9.11×10^{-31} kg

Planck's constant h = 6.63×10^{-34} J s

Speed of light = 3.00×10^{8} m

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