# 國立中山大學102學年度碩士暨碩士專班招生考試試題

科目名稱：工程數學【材光系碩士班乙組】　　題號：439001

※本科目依簡章規定「可以」使用計算機（廠牌、功能不拘）　　

1. Solve $(2y^2 - 9xy)dx + (3xy - 6x^2)dy = 0$ (15%)

2. Evaluate $\oint_C x^2 y dx - xy^2 dy$, where $C$ is the boundary of the region (15%)

$x^2 + y^2 \le 4, \quad x \ge 0, \quad y \ge 0$

3. The Legendre polynomial as a polynomial solution of the Legendre equation

$(1-x^2)y'' - 2xy' + n(n+1)y = 0$, where $n = 0, 1, 2,$

From $(1-2xr+r^2)^{-1/2} = \sum_{n=0}^{\infty} P_n(x) r^n$, calculate $\int_{-1}^{1} [P_n(x)]^2 dx$ (20%)

4. (a). Find the eigenvalues, eigenfunctions and verify the orthogonality of the obtained eigenfunctions for the following initial value problem of the differential equation.

$y'' + 8y' + (\lambda + 16)y = 0, \; y(0) = 0, \; y(\pi) = 0$ (15%)

(b). Based on the answer of (a), determine the Fourier coefficient for $f(x) = e^{4x}$ and $p(x)$=1. (10%)

5. Find the temperature $u(x,t)$ of one − dimensional heat equation, $\frac{\partial u}{\partial t} = c^2 \frac{\partial^2 u}{\partial x^2}$ ($c$ is a constant), for an adiabatic bar (length = L) satisfying $u(x,0) = f(x)$. (15%)

6. Find the Laplace integral, $\int_0^{\infty} \frac{\cos\omega x}{k^2 + \omega^2} d\omega = \frac{\pi e^{-kx}}{2k}$, through the Fourier cosine integral of $f(x) = e^{-kx}$, where $x > 0$ and $k > 0$ (show the details of your work). (10%)

# 國立中山大學102學年度碩士暨碩士專班招生考試試題

科目名稱：光電概論【材光系碩士班丙組】　　題號：439002

※本科目依簡章規定「可以」使用計算機（廠牌、功能不拘）　　

1. A device used to measure the radius of curvature of the cornea of the eye is called a keratometer (also known as a ophthalmometer), which is a diagnostic instrument for measuring the curvature of the anterior surface of the cornea, particularly for assessing the extent and axis of astigmatism. This is useful information when fitting contact lenses. In effect, an illuminated object is placed a known distance from the eye, and the image reflected off the cornea is observed. The instrument allows the operator to measure the size of the virtual image. If the magnification is found to be $0.035\times$ when the object distance is set at $100\,mm$, what is the radius of curvature? (10 %)

2. *A Bar at the Folies-Bergère* (Fig. 1), painted and exhibited at the Paris Salon in 1882, was the last major work by French painter ***Édouard Manet***. This paint shows a girl standing in front of a large planar mirror. Reflected in it is her back and a man in evening dress (on the right corner) with whom she appears to be talking. It would seem that ***Manet***'s intent was to give the uncanny feeling that the viewer is standing where the gentleman must be. From the laws of Geometrical Optics, what is wrong? (10 %)

Fig. 1

3. Two particles, each of mass $m$ and having charge $q$, are suspended by very thin nonconducting strings of length $l$ from a common point $P$. If the size of the particles is so small, compared to the separation. Find the angle $\theta$ that each string makes with the vertical. (10 %)

4. An electrophorus is a simple manual capacitive generator used to produce electrostatic charge via the process of electrostatic induction. One such instrument consists of a flat circular plate of wax and a similar plate of metal with an insulating handle. The wax plate is given a bound charge $Q$ by rubbing it with fur. Then the metal plate is laid on the wax plate and temporarily grounded, so that it acquires a charge $-Q$. The metal plate is finally removed from the wax plate, retaining its charge $-Q$. Suppose the radius of the plates is $10\,cm$, $Q = 0.5\,\mu C$, and the initial separation of the two plates is $10^{-6}\,m$. Find the potential difference between the plates and the stored energy when the separation is

(a) $d = 10^{-6}\,m$, (10 %)

(b) $d = 0.02\,m$. (10 %)

5. Two particles, each of mass $m$ and having charge $q$, are suspended by very thin nonconducting strings of length $l$ from a common point $P$. If the size of the particles is so small, compared to the separation. Find the angle $\theta$ that each string makes with the vertical. (10 %)

6. Augustin Louis Cauchy (1789 – 1857) determined an empirical equation for the refractive index $n(\lambda)$ for substances that are transparent in the visible. His expression corresponded to the power series of wavelength

$$n(\lambda) = P_0 + \frac{P_2}{\lambda^2} + \frac{P_4}{\lambda^4} + \ldots$$

where the $P_{2n}$ s are all constants. Later on, in 1871 Sellmeier derived the equation

$$n^2 = 1 + \sum_j \frac{A_j \lambda^2}{\lambda^2 - \lambda_{oj}^2}$$

where the $A_j$ terms are constants and each $\lambda_{oj}$ is the vacuum wavelength associated with a natural frequency $\nu_{oj}$, such that $\lambda_{oj} \cdot \nu_{oj} = c$, where $c = 299{,}792{,}458\,{}^{\mathrm{m}}/_{\mathrm{S}}$ is the speed of light in vacuum. Sellmeier's formulation is a considerable practical improvement over the Cauchy equation mentioned above. Show that where $\lambda >> \lambda_{oj}$, Cauchy's Equation is an approximation of Sellmeier's. (10 %)

7. The following equations describe the plane waves propagating along the positive $z$-direction while the electric field ($\vec{E}$) varying in the xy plane. Express completely the state of polarization of each.

(a) $\vec{E} = E_0 \sin(kz - \omega t)\hat{x} + E_0 \sin(kz - \omega t)\hat{y}$ (5 %)

(b) $\vec{E} = E_0 \cos(kz - \omega t)\hat{x} + E_0 \cos\left(kz - \omega t + \frac{\pi}{2}\right)\hat{y}$ (5 %)

8. Fig. 2 show $4n$ point charges with equal charge $q$ uniformly distributed on the circumference of a circle of radius $R$.

(a) Find the electric field on the specific point to the first order of $\delta$. (i.e. consider $\delta$ is so small that the term $\left(\frac{\delta}{R}\right)^2$ and its higher terms may be neglected.) (10 %)

(b)Assuming the total charge $4nq$ is constant, simplify your answer for the limit $n \to \infty$ and $q \to 0$, and express it in terms of the ring's linear charge density. (10 %)

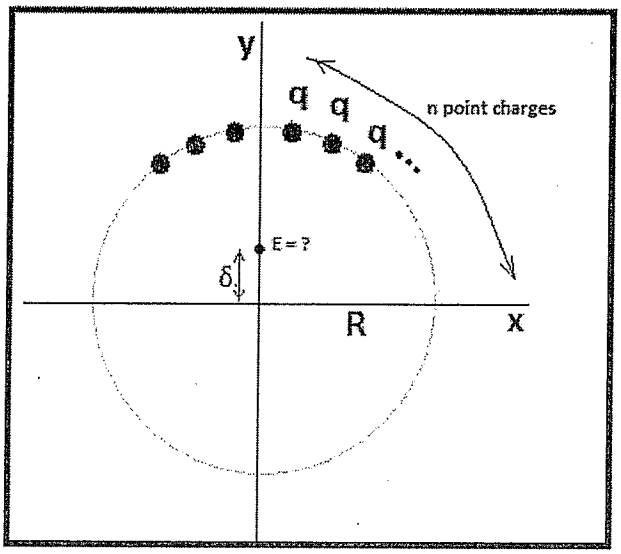



Fig. 2

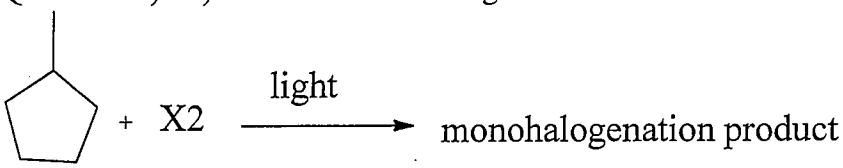
# 國立中山大學102學年度碩士暨碩士專班招生考試試題

科目名稱：有機化學【材光系碩士班甲組】　　題號：439003

※本科目依簡章規定「不可以」使用計算機　　

**1. 選擇題 (單選, Each 2%, Total: 20%)**

Questions 1) - 3) concern the following reaction:




1) ( ) What is the main intermediate involved in the above reaction? (a) Cation; (b) Anion; (c) Radical; (d) Carbene.

2) ( ) Light is involved in which of the following reaction steps? (a) Initiation only; (b) Termination only; (c) Propagation only; (d) Initiation and propagation.

3) ( ) How many monohalogenation products are possible? (Do not consider stereoisomers.) (a) 2; (b) 3; (c) 4; (d) 5.

4) ( ) Which of the statement about allene ($H_2C=C=CH_2$) is correct? (a) The central carbon has $sp^2$ configuration; (b) The two terminal carbons have sp configuration; (c) The four hydrogen atoms lies on two parallel planes; (d) The four hydrogen lies on two planes perpendicular to each other.

5) ( ) The separation of a reaction mixture into the pure enantiomers is termed: (a) Racemization; (b) Resolution; (c) Isomerization; (d) Equilibration.

6) ( ) The reaction of (*R*)-1-chloro-3-methylpentane with sodium iodide in acetone will yield 1-iodo-3-methylpentant that is (a) *R*; (b) *S*; (c) A mixture of *R* and *S*; (d) Meso; (e) None of these.

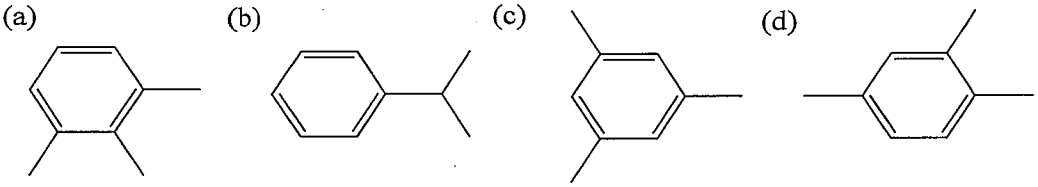
7) ( ) When an organic molecule is irradiated with ultraviolet radiation, the energy absorbed by the molecule corresponds to: (a) The amount necessary to increase molecular motions in functional groups; (b) The amount necessary to excite electrons from one molecular orbital to another; (c) The amount necessary to "flip" the spin of atomic nuclei; (d) The amount necessary to strip a molecule of one electron to generate a radical cation.

8) ( ) What m/z ratio range might be common to many substituted benzene compounds? (a) 72 - 77 ppm; (b) 81 - 88 ppm; (c) 26 - 38 ppm; (d) less than 59 ppm.

9) ( ) In the formation of an addition polymer such as polyvinylchloride: (a) The monomers must have at least one degree of unsaturation; (b) The formation occurs via a polar reaction; (c) The products have the same degree of complexity as biopolymers; (d) The resulting polymer generally contains two types of monomer.

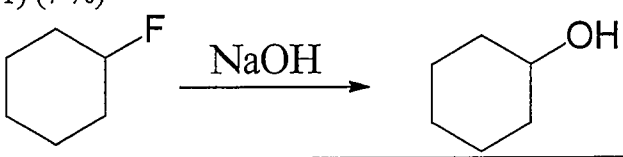
10 ( ) Which of the following had the fewest signals in $^{13}C$ NMR?

(a) (b) (c) (d)

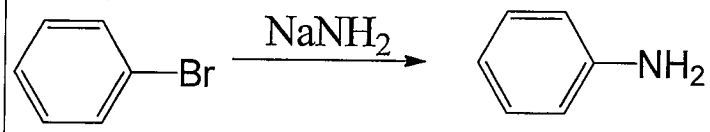


**2. (Total: 30 %)** Most substitutions (or elimination) reactions between substrates and nucleophiles (or base) are strongly influenced by the experimental parameters such as chemical structures of the substrates and the nucleophiles, the leaving group, the applied solvent or the potential side reaction. With appropriate experimental conditions, the expected products from the intended substitution (or elimination) reactions can be obtained without any problem; however, unfavorable experimental conditions failed the reaction. Give the main reason responsible for the failures of the substitution (or elimination) reactions listed below:

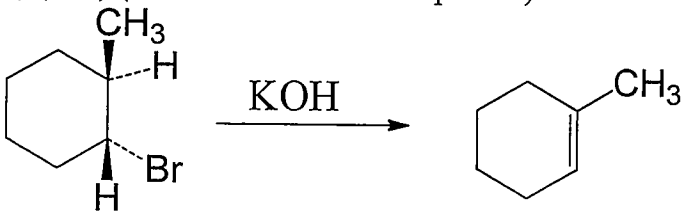
1) (7 %)



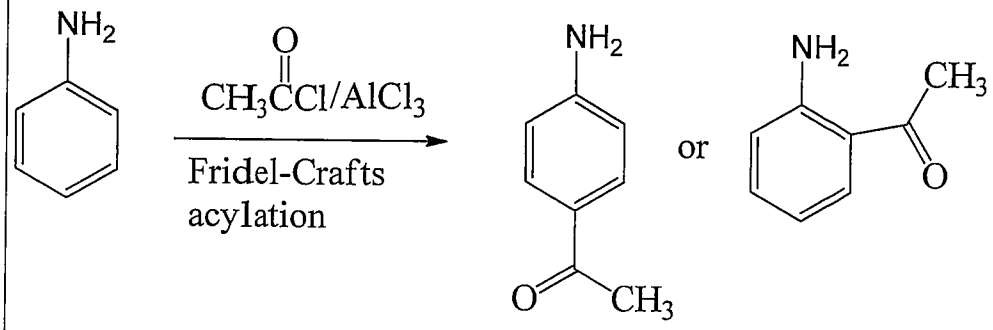
2) (7 %)




3) (8 %) (use the chair form to explain it)




4) (8 %)



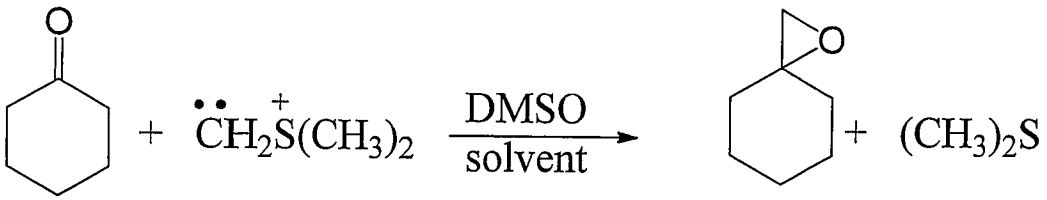

**3. (Each 10 %, Total: 20%)** Infrared and $^1$H NMR spectroscopies are used to evaluate the real structure of organic compounds. With the known chemical formula, the real structures of the following compounds can be easily confirmed. Suggest the structures that are consistent with the molecular formula and spectroscopic properties of each of the following:

1) $C_3H_5ClO_2$
IR ($cm^{-1}$), 1720, 3300-2500
$^1$H NMR (δ): 2.9 triplet (2H); 3.8 triplet (2H) and 11.7 singlet (1H)

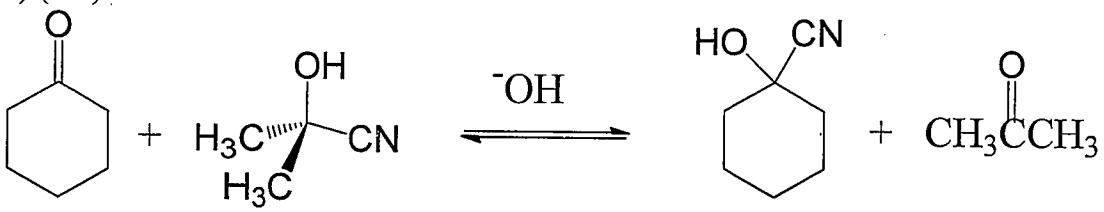
2) $C_5H_{10}O_2$
IR ($cm^{-1}$), 2750, 1740
$^1$H NMR (δ): 1.2 singlet (6H); 3.5 singlet (3H) and 9.7 singlet (1H)

**4. (Each 6%, total: 30 %)** Write down the mechanistic steps involved in the following reactions.

1) (6%)




2) (6%)



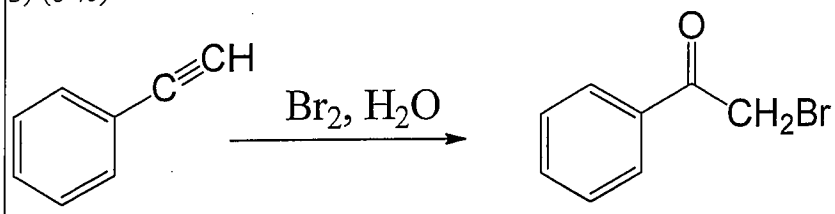
# 國立中山大學102學年度碩士暨碩士專班招生考試試題

科目名稱：有機化學【材光系碩士班甲組】　　題號：439003

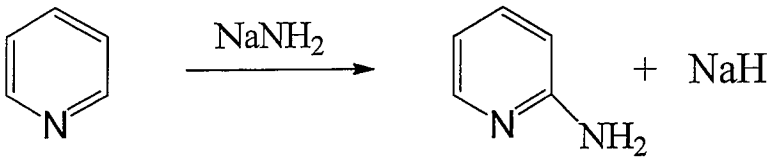
※本科目依簡章規定「不可以」使用計算機



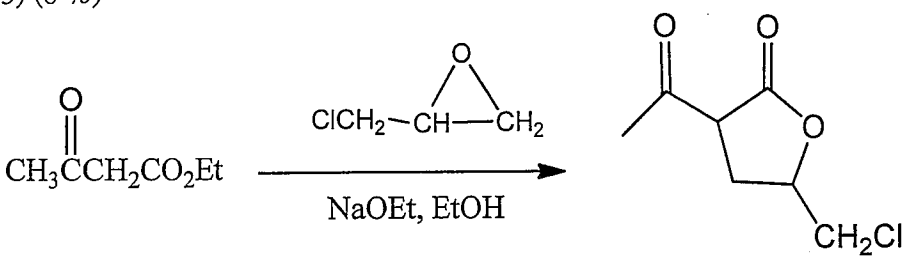
3) (6 %)




4)(6 %)




5) (6 %)

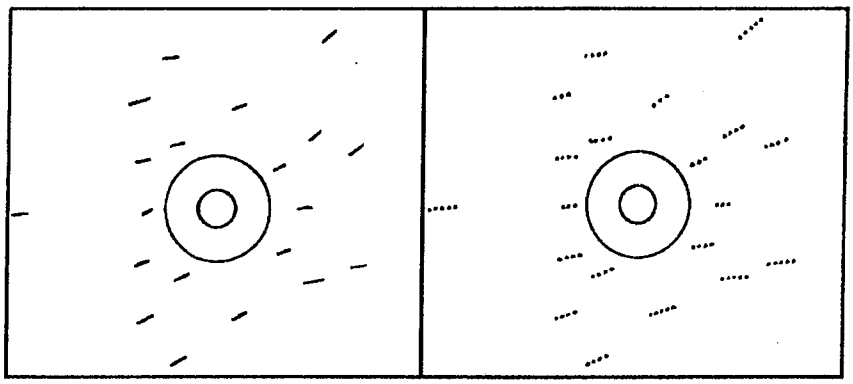


# 國立中山大學102學年度碩士暨碩士專班招生考試試題

科目名稱：材料科學【材光系碩士班丙組】　　題號：439004

※本科目依簡章規定「可以」使用計算機（廠牌、功能不拘）　　共2頁第1頁

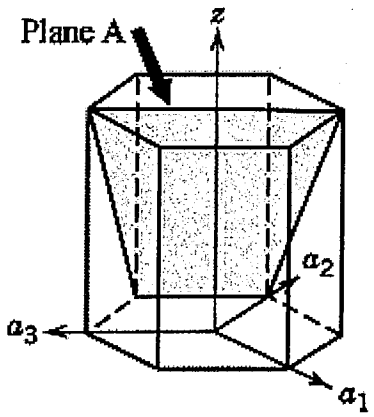
(1) Two schematic Laue patterns are given below, showing how polygonization breaks up asterated X-ray reflections into a series of discrete spots. Explain the reason for this. 8 points




(2) For a material to be deformed plastically, dislocations need to be generated and slipped in the material. Shear stress is required to let dislocations slip in a material. Dislocations can slip in some materials under a relatively low shear stress, however, there are methods which can let dislocations need a higher shear stress to slip in the material. Give the methods that you know can make dislocations more difficult to slip in a material. Explain the mechanisms of these methods.

10 points

(3) The figure shown below is the unit cell of a hexagonal close-packed crystal. What is the Miller-Bravais indices of plane A? And what is the angle between the (0001) basal plane and plane A? The c/a ratio of this crystal is 1.624. 8 points




(4) Derive the Fick's first law of diffusion in interstitial solid solutions. 10 points

(5) Give a schematic drawing of the morphology of grains after secondary recrystallization. 8 points

(6) What is the function of a p-n junction? Explain how does it work? 10 points

# 國立中山大學102學年度碩士暨碩士專班招生考試試題

科目名稱：材料科學【材光系碩士班丙組】　　題號：439004

※本科目依簡章規定「可以」使用計算機（廠牌、功能不拘）　　

(7) Some alloy steels can be hardened by quenching the steels from the austenite phase temperature to room temperature to obtain martensite structure. Martensite is a very strong phase, it has very high strength, but it does not have good toughness and ductility. What method you can do to improve the toughness and ductility of the martensite? What is the change of the microstructure after your method? 10 points

(8) Draw a hypothetic (假定) binary phase diagram which consists of a eutectic and a peritectic reaction. In this diagram mark (a) solidus line, (b) liquidus line, (c) eutectic temperature, (d) peritectic composition, and (e) solvus line. 10 points

(9) Explain the following terms. (a) semicoherent phase boundary, (b) jog, (c) creep, (d) fatigue limit, (e) refractory metals, (f) coring, (g) interface-controlled growth, (h) soft magnetic materials. 16 points

(10) Metals are known to be good electric conductors. The resistivity of a metal is very low, however, several factors may cause the resistivity of a metal to be increased. What are these factors? Why these factors can increase the resistivity of the metal? 10 points

# 國立中山大學102學年度碩士暨碩士專班招生考試試題

科目名稱：物理化學【材光系碩士班甲組】　　題號：439005

※本科目依簡章規定「可以」使用計算機（廠牌、功能不拘）　　

1. The density of water vapor at 327.6 atm and 776.4 K is 133.2 g/L. Determine the molar volume $V_m$ of water and the compression factor $Z$ from these data. In addition, calculate $Z$ from the van der Waals equation with $a$ = 5.464 $L^2$ atm/$mol^2$, and $b$ = 0.03049 L/mol. Please comment the difference about these two data about $Z$. (15%)

2. A sample of 1.0 mol of perfect gas with $C_v$ = 20.8 J/K is initially at 3.25 atm and 310 K. It undergoes reversible adiabatic expansion until its pressure reaches 2.50 atm. Calculate the final volume and temperature and the work done. (10%)

3. An ideal gas expands from initial volume from $V_i$ to final volume $V_f$. Calculate the changes $\triangle U$, $Q$ and $W$ for the gas (in terms of $n$, $T$, $V_i$ and $V_f$).
   (a) If the expansion is free expansion (5%)
   (b) If the expansion is adiabatic, and starts at temperature $T_0$. (5%)
   (c) If the expansion is isothermal at temperature $T_0$. (5%)

4. Consider a perfect gas contained in a cylinder and separated by a frictionless adiabatic piston into two sections A and B. All changes in B are isothermal; that is, a thermostat surrounds B to keep its temperature constant. There is 2.0 mol of the gas in each section. Initially $T_A = T_B$ = 300 K, $V_A = V_B$ = 2.0 L. Heat is added to Section A and the piston moves to the right reversibly until the final volume of Section B is 1.0 L. Calculate $\Delta S_A$ and $\Delta S_B$. (10%)

5. The chemical shift of the $CH_3$ protons in acetaldehyde (ethanal) is $\delta$ = 2.20 and that of the CHO proton is 9.80. What is the difference in local magnetic field between the two regions of the molecule when the applied field is (a) 1.5 T, and (b) 15 T. (10%)

6. Sketch the form of an AMX NMR spectrum, where A, M, and X are protons with distinctly different chemical shift and $J_{AM} > J_{AX} > J_{MX}$. (10%)

7. Cotton consists of the polymer cellulose, which is a linear chain of glucose molecules. The chains are held together by hydrogen bonding. When a cotton shirt is ironed, it is first moistened, and then heated under pressure. Explain this process. (10%)

8. The diffusion coefficient of $CCl_4$ in heptanes at 25 °C is $3.17\times10^{-9}$ $m^2/s$. Estimate the time required for a $CCl_4$ molecules to have a root mean square displacement of 5.0 mm. (10%)

9. Derive the rate law for the decomposition of ozone in the reaction $2O_3(g) \rightarrow 3O_2(g)$ on the basis of the following proposed mechanism:

$$(1)\ O_3 + M \underset{k_{-1}}{\overset{k_1}{\Leftrightarrow}} O_2 + O + M$$

$$(2)\ O_3 + O \xrightarrow{k_2} 2O_2$$

(10%)

# 國立中山大學102學年度碩士暨碩士專班招生考試試題

科目名稱：熱力學【材光系碩士班乙組】　　題號：439006

※本科目依簡章規定「可以」使用計算機（廠牌、功能不拘）　　

（請依序作答，標示題號，並注意單位）

1. Methane is delivered at 298 K to a glass factory, which operates a melting furnace at 1600 K. The fuel is mixed with a quantity of air, also at 298 K, which is 10% in excess of the amount theoretically needed for complete combustion. (Air is approximately 21% $O_2$ and 79% $N_2$).
   (a) Assuming complete combustion, what is the composition of the flue gas (the gas following combustion)? (10%)
   (b) What is the temperature of the gas, assuming no heat loss? (10%)

| Data | For | $\Delta H_{298}$ [kcal/(g.mole)] | Cp [cal/mole.K] |
|---|---|---|---|
| | $CH_4$ | -17.89 | 16 |
| | $CO_2$ | -94.05 | 13.7 |
| | $H_2O$ | -57.80 | 11.9 |
| | $N_2$ | | 8.2 |
| | $O_2$ | | 8.2 |

2. Metals exhibit some interesting properties when they are rapidly solidified from the liquid state. An apparatus for the rapid solidification of copper is cooled by water. In the apparatus, liquid copper at its melting point (1356 K) is sprayed on a cooling surface, where it solidifies and cools to 400 K. The copper is supplied to the apparatus at the rate of one kilogram per minute. Cooling water is available at 20 °C, and is not allowed to rise above 80 °C. What is the minimum flow rate of water in the apparatus, in cubic meter per minute? Clearly state the system and basis for your calculation. (20%)

| Data | | |
|---|---|---|
| | For water: | Cp = 1 cal/g.K |
| | | Density = 1 g/cm$^3$ |
| | For copper: | molecular weight = 63.54 g/mol |
| | | Cp (solid) = 5.4 cal/(mol.K) |
| | | Heat of fusion = 3120 cal/mol |

3. A great deal of effort has been expended to find "high temperature superconductors": materials that are superconductors at temperatures higher than the boiling point of liquid nitrogen (77 K). Most of the older superconductors had to be operated with liquid helium (boiling point 4.2 K) as the cooling fluid. To estimate the savings possible in operating costs through the use of the "high temperature" superconductors, calculate the minimum work needed to compensate for a heat leak of 1 kJ into the superconductor for both "high temperature" superconductors and the older ones. Assume that the ambient temperature is 300 K. (20%)

4. An alloy composed of 30 wt% Zirconium and 70 wt% Columbium is being slowly cooled from 2400 °C during processing. Equilibrium is maintained at each temperature. Use the accompanying Cb-Zr phase diagram to answer parts (a) ~(c)
   (a) At what temperature does the first solid form and what is the composition of the solid? (5%)
   (b) At what temperature does the last liquid solidify, and what is the composition of the last liquid? (5%)
   (c) Plot the molar Gibbs free energy of mixing ($\Delta G_{mix}$) of each phase and show their relationships with equilibrium phase compositions at 2000 °C and 800 °C respectively. (30%)

# 國立中山大學102學年度碩士暨碩士專班招生考試試題

科目名稱：熱力學【材光系碩士班乙組】　　題號：439006

※本科目依簡章規定「可以」使用計算機（廠牌、功能不拘）