

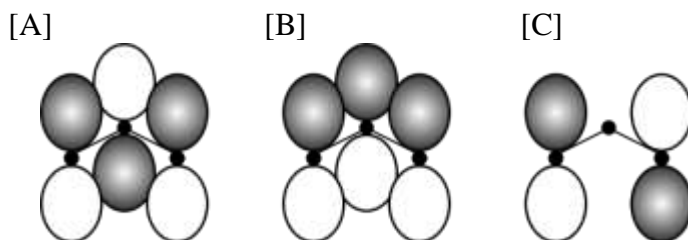
6. Put the correct sign (“<” or “>”) for the comparison of orbital energies below for a many-electron atom (4%)
- (a) ϵ_{2s} ϵ_{3s} (b) ϵ_{3p} ϵ_{3s} (c) ϵ_{7f} ϵ_{6p} (d) ϵ_{4p} ϵ_{3d}
7. What is the electron configuration for (6%)
- (a) an atom with 33 electrons
 (b) an atom with 48 electrons
 (c) an atom with 95 electrons.
- All of the atoms are in their ground states.
8. In a set of atoms and ions given by {Al³⁺, O²⁻, C, Na⁺, B⁵⁺, N³⁻, Cl⁻, F⁻, Ne, Mg²⁺} identify the subset of atoms and ions containing 10 electrons. (3%)
9. Answer the questions: (4%)
- (a) Which ion do you expect to have larger ionic radius: Fe³⁺ or Fe²⁺?
 (b) Which atom do you expect to have larger atomic radius: Na or K?
 (c) Which atom/ion do you expect to be larger: Cl or Cl⁻?
 (d) Which atom/ion do you expect to be larger: Pb or Pb⁴⁺?
10. The atomic number of an element is 75. Is this element diamagnetic or paramagnetic? Why? (3%)
11. (a) Sketch the three possible Lewis structures that satisfy the octet rule for the molecule CH₂O.
 (b) Determine the formal charge of each atom and identify the most likely Lewis structure. (6%)
12. (a) Draw the Lewis structure of CN⁻ ion. (2%)
 (b) Sketch the molecular orbital diagram. (3%)
 (c) Write its electron configuration and determine its bond order. (3%)
 (d) According to the bond order, predict and arrange the following species (from large to small) according to their bond length: CN⁺, CN, CN⁻. (2%)
 (e) Indicate the magnetic property of O₂⁺, O₂ and O₂²⁻. (3%)
13. (a) What does LCAO-MO stand for? (2%)
 (b) Sketch the σ and σ^* molecular orbitals (MO) formed by one 2s and one 2p atomic orbitals (AO), and the π and π^* MO formed by two 2p AO. Show the nodal plane (if there is any) of each MO and AO. (4%)

14. Please fill in the table: (12%)

	Lewis structure	geometry	hybridization of the S atom	polar or nonpolar
SF ₄				
SF ₅ ⁻				
SF ₆				

15. So-called greenhouse gases, which contribute to global warming have a dipole moment or can be distorted into shapes that have a dipole moment. Which of the following gases are greenhouse gases? N₂, O₂, O₃, Ar, H₂O, CO₂, SO₂, NO₂, N₂O, or CH₄. (4%)

16. The surface boundary plots of the three π molecular orbitals A, B, and C in ozone (O₃) are shown as:



And there are four electrons in these orbitals. Please answer the following questions

- Indicate the nonbonding orbital. (Or none of them is a nonbonding orbital.) (1%)
- Which of these three orbitals has the highest energy? (1%)
- Are there any degenerate orbitals? If yes, please indicate them. (2%)
- Indicate the HOMO and LUMO within this π -system. (2%)

17. Why are chiral molecules said to be “optically active”? (3%)

105A Chemistry (I) Midterm Exam

Answer

1. 各 2%

- (a) explain blackbody radiation with quantum theory, $E = nh\nu$
- (b) photoelectric effect, electromagnetic waves as particles, photons.
- (c) wavefunction, fundamental equation of quantum mechanics.

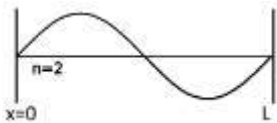
2. 各 2%

- (a) angular momentum $L = m_eur = nh/2\pi = n\hbar$
- (b) electrons circulate the atom as standing waves, $2\pi r = n\lambda$,
matter wave equation $\lambda = h/mu$
 $L = m_eur = m_eun\lambda/2\pi = m_eunh/2\pi m_eu = nh/2\pi$

3. (a) 6% ; (b)(c)各 2%

- (a) $\psi(0) = 0 ; \psi(L) = 0 ;$ normalization: find the value of k for $\int_0^L \psi^2(x)dx = 1$

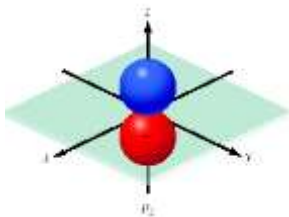
(b)



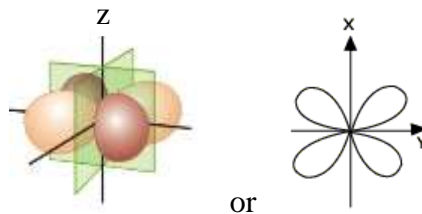
- (c) $3h^2 / 8mL^2$

4. (a) 4% ; (b) 2% ; (c) 2%

- (a) $2p_z$



- $3d_{xy}$



(nodal planes 不用畫，但座標軸標示要能看出 orbital 方向)

- (b) A node is a region in space where ψ passes through 0.
- (c) $2p_z$: 0 in radial and 1 in angular ; $3d_{xy}$: 0 in radial and 2 in angular

5. It is a rule saying that no two electrons in an atom can have the same set of four quantum numbers (n, l, m_l, m_s) 2%

6. 各 1% (a) $\epsilon_{2s} < \epsilon_{3s}$ (b) $\epsilon_{3p} > \epsilon_{3s}$ (c) $\epsilon_{7f} > \epsilon_{6p}$ (d) $\epsilon_{4p} > \epsilon_{3d}$

7. 各 2%

(a) $[\text{Ar}] 4s^2 3d^{10} 4p^3$ or $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^3$

(b) $[\text{Kr}] 5s^2 4d^{10}$ or $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10}$

(c) $[\text{Rn}] 7s^2 5f^7$ or $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^{10} 6p^6 7s^2 5f^7$

8. $\text{Al}^{3+}, \text{O}^{2-}, \text{Na}^+, \text{N}^{3-}, \text{F}^-, \text{Ne}, \text{Mg}^{2+}$ 3% , 多或少一個扣 1% , 扣完為止

9. 各 1% (a) Fe^{2+} (b) K (c) Cl^- (d) Pb

10. Paramagnetic 2%

because it has unpaired electrons and non-zero magnetic moment 1%

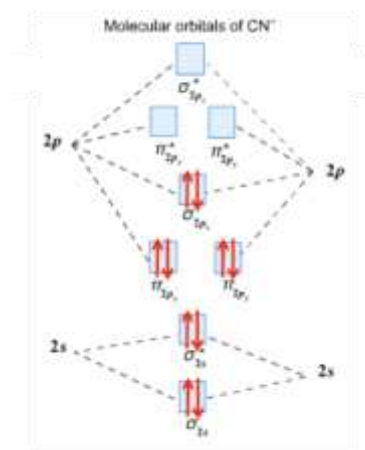
11. 共 6%

The most likely Lewis structure for CH_2O



12. (a) $[:\text{C}\equiv\text{N}:]^-$ 2%

(b)



3%

(c) $\text{CN}^- (s_{1s})^2 (s_{1s}^*)^2 (s_{2s})^2 (s_{2s}^*)^2 (p_{2p_x})^2 (p_{2p_y})^2 (s_{2p_z})^2$
or $\sigma_{2s}^2 \sigma_{2s}^{*2} \pi_{2p}^4 \sigma_{2p}^2$

bond order = 3 3%

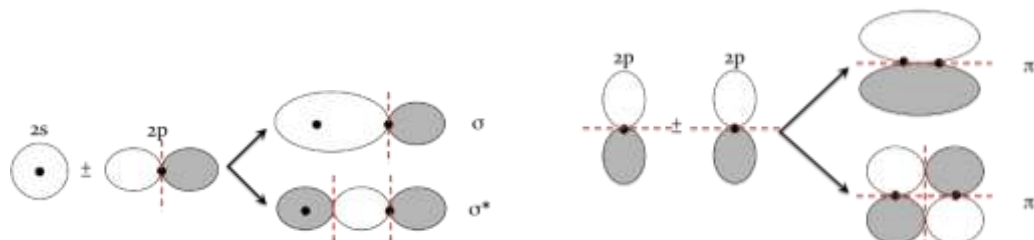
(d) From large to small: $\text{CN}^+, \text{CN}, \text{CN}^-$ 2%

(e) O_2^+ and O_2 : paramagnetic ; O_2^{2-} : diamagnetic 3%

13. (a) 2% , (b) 4%

(a) Linear combination of atomic orbitals – Molecular orbital

(b)



14. 每格 1% , 分子形狀可寫中文

	Lewis structure	geometry	hybridization of the S atom	polar or nonpolar
SF_4		distorted tetrahedral or seesaw	sp^3d	polar
SF_5^-		square pyramidal	sp^3d^2	polar
SF_6		octahedral	sp^3d^2	nonpolar

15. $O_3, H_2O, CO_2, SO_2, NO_2, N_2O, CH_4$ 4% , 多或少一個扣 1% , 扣完為止

16. 各 1% (a) C ; (b) A

各 2% (c) No ; (d) HOMO: C , LUMO: A

17. Chiral molecules rotate the plane of polarization of polarized light as it passes through them. (textbook p.255) 3%