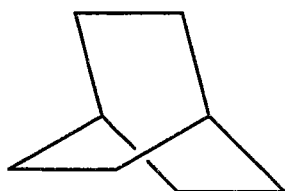


選擇題：單選題（只有一個答案對，答錯不倒扣，每一題兩分，總分100）

- Modern periodic table is arranged in a sequence based on the property of :
(A) Electronegativity (B) Ionization Energy (C) Atomic Weight
(D) Atomic number (E) Atomic radius
 - Which element is in liquid form at $T = 50\text{ }^{\circ}\text{C}$
(A) Antimony (B) Gallium (C) Sulfur (D) Carbon (E) Sodium
 - What is the scientific contribution for the 2011 Nobel Laureate Dr. Dan Shechtman?
(A) Discovered the icosahedral phase of quasicrystalline crystals
(B) Pioneering work on graphene.
(C) Developed the cathode material of Li-ion battery
(D) Discover the buckminsterfullerene
(E) For the discovery of new superconducting materials
 - Which of the following molecules is the strongest Lewis acid?
(A) NF_3 (B) SbF_5 (C) KCl (D) PCl_3 (E) SnCl_2
 - Identify the point group of SbF_4^-
(A) T_d (B) C_{2h} (C) C_{2v} (D) D_{2d} (E) D_{4h}
 - Identify the point group of SeF_3^+
(A) D_{3h} (B) C_{3v} (C) C_{2v} (D) C_{2h}
 - Which of the following molecule in liquid form exhibits paramagnetic property?
(A) NH_3 (B) CO_2 (C) O_2 (D) N_2 (E) H_2
 - The crystals of CeO_2 exhibit a fluorite structure with a coordination number of 4 for the anion. What is the coordination number of the cation?
(A) 4 (B) 6 (C) 8 (D) 10 (E) 12
 - Which of the following element/compound does NOT exhibit a layer structure in the solid state?
(A) Cadmium Iodide (B) Titanium Dioxide (C) Graphite
(D) Molybdenum disulfide (E) Boron nitride
 - Identify the crystal system with $a \neq b \neq c$, $\alpha = \gamma = 90^\circ$, $\beta > 90^\circ$.
(A) Cubic (B) Monoclinic (C) Orthorhombic (D) Hexagonal (E) Triclinic
- The questions 11 and 12 are for the molecule Buckminsterfullerene C_{60} molecule.
- Identify the point group of Buckminsterfullerene.
(A) D_{5h} (B) T_d (C) I_h (D) O_h (E) C_{5v}
 - How many symmetrically independent carbon atom(s) for a C_{60} molecule?
(A) 1 (B) 2 (C) 4 (D) 5 (E) 10

注意：背面有試題

Questions 13 and 14 are related to the molecule C_8H_{14} bicyclo[2.2.2]octane shown below:



bicyclo[2.2.2]octane

13. Identify the point group of bicyclo[2.2.2]octane

- (A) C_3 (B) C_{3v} (C) C_{3h} (D) D_{3d} (E) D_{3h}

14. How many peaks will you expect from the 1H NMR spectrum for the molecule bicyclo[2.2.2] octane?

- (A) 1 (B) 2 (C) 3 (D) 4 (E) 5

Questions 15 and 17 are related to the molecule XeF_4 and the corresponding character table with hidden point group symbol is shown below:

?	E	$2C_4$	C_2	$2C_2'$	$2C_2''$	i	$2S_4$	σ_h	$2\sigma_v$	$2\sigma_d$
A_{1g}	1	1	1	1	1	1	1	1	1	1
A_{2g}	1	1	1	-1	-1	1	1	1	-1	-1
B_{1g}	1	-1	1	1	-1	1	-1	1	1	-1
B_{2g}	1	-1	1	-1	1	1	-1	1	-1	1
E_g	2	0	-2	0	0	2	0	-2	0	0
A_{1u}	1	1	1	1	1	-1	-1	-1	-1	-1
A_{2u}	1	1	1	-1	-1	-1	-1	-1	1	1
B_{1u}	1	-1	1	1	-1	-1	1	-1	-1	1
B_{2u}	1	-1	1	-1	1	-1	1	-1	1	-1
E_u	2	0	-2	0	0	-2	0	2	0	0

15. Identify the point group of XeF_4

- (A) C_4 (B) C_{4h} (C) C_{4v} (D) D_{4h} (E) D_{4d}

16. Identify the irreducible representation of d_{xy} orbital.

- (A) A_{1g} (B) A_{2g} (C) B_{1g} (D) B_{2g} (E) A_{1u}

17. What is the order for the point group of XeF_4

- (A) 10 (B) 12 (C) 14 (D) 16 (E) 18

注意:背面有試題

18. Which of the following element/compound is an p-type semiconductor?

- (A) Silicon Carbide (B) Diamond (C) Boron Nitride
(D) Arsenic-doped Germanium (E) Gallium-doped Germanium

19. Which of the following species is paramagnetic in its ground state?

- (A) O_2^{2-} (B) CO (C) F_2 (D) CN^- (E) NO

The questions 20 and 21 are related to the molecule $[Fe(CO)_5]$ with D_{3h} point group.

D_{3h}	E	$2C_3$	$3C_2$	σ_h	$2S_3$	$3\sigma_v$		
A_1'	1	1	1	1	1	1		$x^2 + y^2, z^2$
A_2'	1	1	-1	1	1	-1	R_z	
E'	2	-1	0	2	-1	0	(x, y)	$(x^2 - y^2, xy)$
A_1''	1	1	1	-1	-1	-1		
A_2''	1	1	-1	-1	-1	1	z	
E''	2	-1	0	-2	1	0	(R_x, R_y)	(xz, yz)

20. How many vibration modes for $[Fe(CO)_5]$ molecule?

- (A) 12 (B) 14 (C) 16 (D) 27 (E) 40

21. Identify the following irreducible representation for CO stretches that is IR active and Raman inactive.

- (A) A_1' (B) A_2' (C) E' (D) A_1'' (E) A_2''

22. How many unpaired electrons are there in a Co^{3+} ion?

- (A) 2 (B) 3 (C) 4 (D) 5 (E) 6

23. Which of the following compounds is the strongest base in water?

- (A) B_2O_3 (B) CO_2 (C) Cl_2O (D) K_2O (E) P_4O_{10}

24. Which rotation symmetry operation is NOT allowed for the crystalline solid with 3D structure

- (A) 2 fold rotation (B) 3 fold rotation (C) 4 fold rotation (D) 5 fold rotation (E) 6 fold rotation

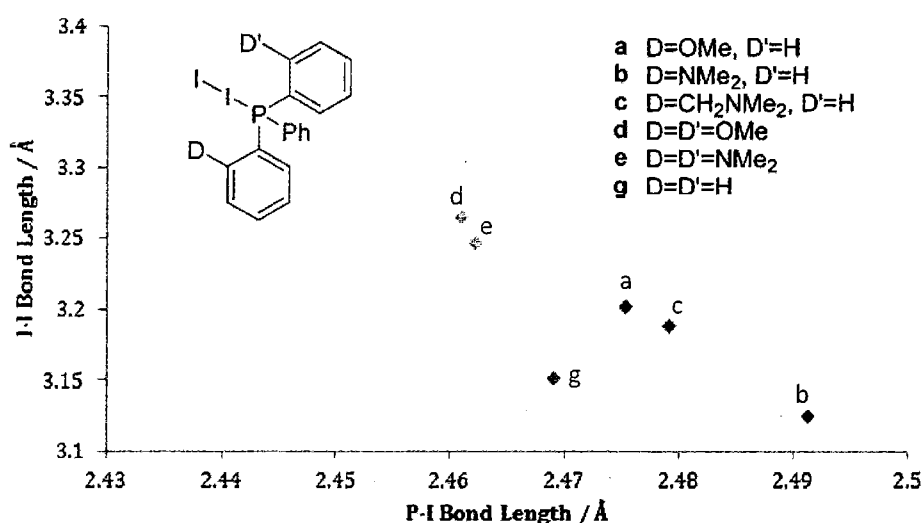
25. How many Na^+ cations in an unit cell of NaCl crystal structure?

- (A) 1 (B) 2 (C) 3 (D) 4 (E) 5

注意:背面有試題

26. Given phosphine- I_2 (Ar_3P-I_2) adducts and the correlations between their P-I and I-I bond lengths are shown below. How many of following statement(s) is/are correct?

- (i) Phosphines forms Lewis acid-base adducts with I_2 , in which phosphines are Lewis base and I_2 is Lewis acidic.
- (ii) Generally, stronger phosphine donors result in the Ar_3P-I_2 adduct with shorter I-I bond length.
- (iii) The I-I bond lengthening is attributed to the donation from phosphine ligands into π^* orbitals of I_2 .
- (iv) The I-I bond lengths of Ar_3P-I_2 adducts are longer than that of I_2 .
- (v) Steric hindrance caused by the ortho-substituents does not influence the magnitude of the P-I and I-I bond lengths.



(A) 1 (B) 2 (C) 3 (D) 4 (E) 5

27. For ditungsten W_2 molecule, what is the possible maximum bond order for it?

(A) 3 (B) 4 (C) 5 (D) 6 (E) 7

28. Following the Q27, what is the electron count for W in W_2 molecule?

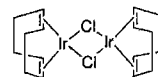
(A) 10 (B) 12 (C) 14 (D) 16 (E) 18

29. Assume that Hund's rule holds for all the systems considered in this problem, and $L-S$ coupling is applicable for all systems. Which of the following has 7S_3 as its ground term?

(A) V (B) Cr (C) Mn (D) Fe (E) Co

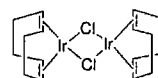
30. Which of the following ions or molecules do you expect to be paramagnetic?

(A) $[Fe(CO)_5]$ (B) $[Fe(CN)_6]^{2+}$ (C) $[Cu(CH_3CN)_4]^+$ (D) $[CoF_6]^{3-}$ (E)



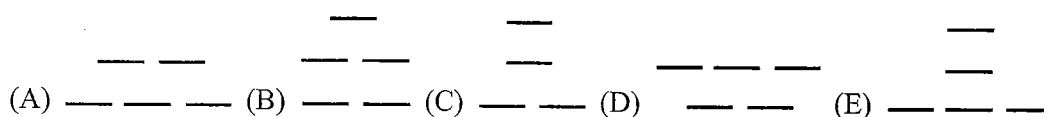
31. Which of the following ions or molecules do you expect to be colorless?

(A) $[Fe(CO)_5]$ (B) $[Fe(CN)_6]^{2+}$ (C) $[Cu(CH_3CN)_4]^+$ (D) $[CoF_6]^{3-}$ (E)



注意:背面有試題

32. What d orbital splitting diagram would you expect for $\text{Fe}(\text{CO})_5$ molecule?



33. The electronic configuration of the boron atom is $1s^2 2s^2 2p^1$. You expect the electron probability about a boron atom in free space is found to be _____.

- (A) tetrahedral (B) spherically symmetric (C) dumbbell shaped (D) double-dumbbell shaped (E) octahedral

34. Which of the following ions or molecules do you expect to have the shortest S–N bond?

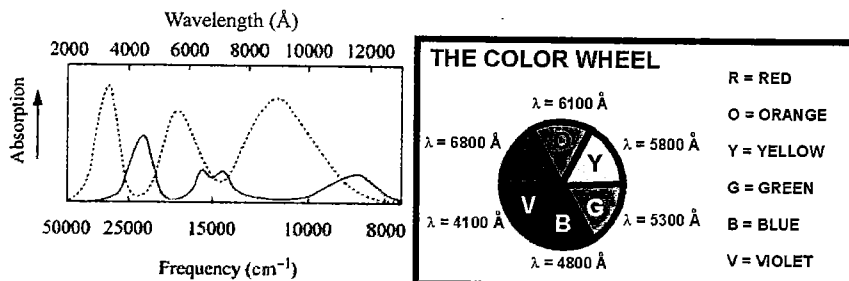
- (A) $\text{PhSO}_2(\text{NH}_2)$
 (B) NS_2^+ (where N is the central atom)
 (C) S_2N_2 (with a square planar structure having only one type of S–N bond)
 (D) N_2S (where N is the central atom)
 (E) NSF_3 (where S is the central atom)

35. Both CrO_4^{2-} and MnO_4^- are very colorful. What type of electronic transitions is responsible for the colors of the complexes?

- (A) d-d transitions
 (B) Interligand electron transfer
 (C) Metal–metal-to-ligand charge transfer
 (D) Metal-to-ligand charge transfer
 (E) Ligand-to-metal charge transfer

36. The absorption spectra of $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$ and $[\text{Ni}(\text{en})_3]^{2+}$ (en = ethylenediamine) are shown in the figure below, along with a color wheel. How many of the following statement(s) is/are correct?

- (i) The dotted-curve belongs to $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$
 (ii) The color of $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$ is orange
 (iii) The color of $[\text{Ni}(\text{en})_3]^{2+}$ is purple
 (iv) Only $[\text{Ni}(\text{en})_3]^{2+}$ exhibits absorption in near-infrared region
 (v) Both $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$ and $[\text{Ni}(\text{en})_3]^{2+}$ have an inversion center and their absorption bands should be intense.



- (A) 1 (B) 2 (C) 3 (D) 4 (E) 5

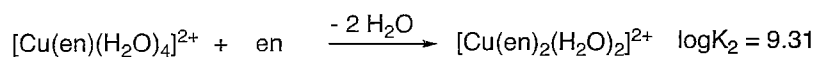
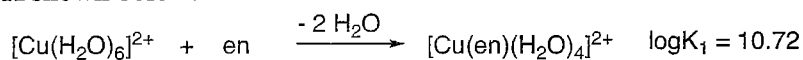
37. Which of the following fragments do you expect to be isolable with CH_2 ?

- (A) CpCu (Cp = C_5H_5) (B) $\text{Mn}(\text{CO})_5$ (C) $\text{Cr}(\text{CO})_4$ (D) $\text{Ni}(\text{CO})_4$ (E) CpCo

38. Which of the following ions do you expect to exhibit the greatest observed magnetic moment?
 (A) $[\text{Ni}(\text{NH}_3)_6]^{2+}$ (B) $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ (C) $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ (D) $[\text{FeF}_6]^{3-}$ (E) $[\text{Fe}(\text{CN})_6]^{3-}$

39. Which ion is mostly kinetically labile?
 (A) Co^{3+} (B) Ru^{2+} (C) Ti^{3+} (D) Cr^{3+} (E) Rh^{3+}

40. The reactions of $\text{Cu}^{2+}(\text{aq})$ ion with en (en = ethylenediamine) feature the equilibrium constants K shown below:



Why is the K_3 significantly smaller than K_1 and K_2 ?

- (A) Jahn-Teller effect
- (B) Trans effect
- (C) Cotton effect
- (D) Hard-Soft Acid-Base Principle
- (E) 18-electron rule

41. For $[\text{Os}_2\text{Cl}_8]^{2-}$ anion, which of the following statements is correct?

- (A) This species should be paramagnetic.
- (B) There is a metal-metal quintuple bond present in this species.
- (C) This ion adopts a staggered conformation.
- (D) The electron count for each Os is 18.
- (E) The oxidation state for Os is +4.

42. Me_2CHMgBr reacts with $\text{Ir}(\text{I})\text{ClL}_3$ to give $\text{Ir}(\text{I})\text{HL}_3$. How many of following statement(s) is/are correct?

- (i) The reaction also produces propene as a by-product.
- (ii) The possible intermediate is $\text{Ir}(\text{CHMe}_2)\text{L}_3$.
- (iii) β -H elimination likely involves in this process.
- (iv) The reaction of Me_2CHMgBr with IrClL_3 likely proceeds through associative mechanism.

(A) 0 (B) 1 (C) 2 (D) 3 (E) 4

43. The reactions of $[\text{PtCl}_4]^{2-}$ with NH_3 (reaction I) and of $[\text{PtCl}_4]^{2-}$ with $[\text{NO}_2]^-$ (reaction II) followed by NH_3 are ways of preparing:

- (A) I: $\text{trans}-[\text{PtCl}_2(\text{NH}_3)_2]$; II: $\text{trans}-[\text{PtCl}_2(\text{NH}_3)(\text{NO}_2)]^-$
- (B) I: $\text{cis}-[\text{PtCl}_2(\text{NH}_3)_2]$; II: $\text{trans}-[\text{PtCl}_2(\text{NH}_3)(\text{NO}_2)]^-$
- (C) I: $\text{cis}-[\text{PtCl}_2(\text{NH}_3)_2]$; II: $\text{cis}-[\text{PtCl}_2(\text{NH}_3)(\text{NO}_2)]^-$
- (D) I: $\text{trans}-[\text{PtCl}_2(\text{NH}_3)_2]$; II: $\text{cis}-[\text{PtCl}_2(\text{NH}_3)(\text{NO}_2)]^-$

注意:背面有試題

44. The kinetics of the isomerization of cis to trans-[Mo(CO)₄(PEt₃)₂] can be followed by IR spectroscopy. Which of the following regions of the IR spectrum would you focus on to monitor the reaction?

- (A) 800-1000 cm⁻¹
- (B) 1400-1600 cm⁻¹
- (C) 1800-2000 cm⁻¹
- (D) 2400-2600 cm⁻¹
- (E) 3000-3500 cm⁻¹

45. Which experimental technique operates on the slowest timescale?

- (A) NMR spectroscopy
- (B) UV-vis spectroscopy
- (C) IR spectroscopy
- (D) Raman spectroscopy
- (E) Photonelectron spectroscopy

46. Which of the following complex has a highest oxidation state of metal?

- (A) (η⁶-C₆H₆)₂Cr
- (B) Na₂[Fe(CO)₄]
- (C) Mn(CO)₅Cl
- (D) Na[(η⁵-C₅H₅)Fe(CO)₂]
- (E) Ni(CO)₄

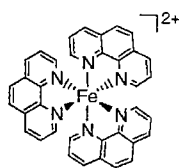
47. If complex [W(Cp)₂(CO)₂] follows 18e- rule. What is Hapticity of Cp?

- (A) 5 and 5 (B) 3 and 5 (C) 3 and 3 (D) 1 and 5 (E) 1 and 3

48. Which of the following is mostly stable?

- (A) [AuF₂]⁻ (B) [AuCl₂]⁻ (C) [AuBr₂]⁻ (D) [AuI₂]⁻ (E) [Au(CN)₂]⁻

49. The intense red of an [Fe(phen)₃]²⁺ (shown below) solution is replaced by pale blue when cerium(IV) sulfate is added to it. Which of the following statements about this observation is correct?



- (A) The intense coloration of [Fe(phen)₃]²⁺ is due to inter-ligand charge transfer.
- (B) The electron count of [Fe(phen)₃]²⁺ is 20.
- (C) Addition of cerium(IV) sulfate causes the reduction of [Fe(phen)₃]²⁺ to [Fe(phen)₃]⁺
- (D) The change of coloration upon the addition of cerium(IV) sulfate is due to lack of ligand to metal charge transfer transitions.
- (E) None of statements are correct.

50. Which of the following is *closo*?

- (A) C₂B₃H₅(CoCp)₂ (B) B₄H₁₀ (C) C₂B₈H₁₂ (D) SB₉H₁₁ (E) P₄