

- 單一選擇 1~25 題，每題 3 分，共計 75 分，答錯不倒扣；簡答題 26~30 題，每題 5 分，共計 25 分。
- 請在答案卷上作答。
- 常數 Avogadro's constant $N = 6.022 \times 10^{23} \text{ mol}^{-1}$

Planck's constant $h = 6.626 \times 10^{-34} \text{ J}\cdot\text{s}$

Gas constant $R = 0.8206 \text{ L}\cdot\text{atm}\cdot\text{K}^{-1}\cdot\text{mol}^{-1} = 8.3145 \text{ J}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$ Faraday constant $F = 96500 \text{ C}\cdot\text{mol}^{-1}$

Speed of light $c = 3 \times 10^8 \text{ m}\cdot\text{s}^{-1}$

Periodic Table of Elements

| | | | | | | | | | | | | | | | | | | |
|--------------------------------------|---------------------------------------|--------------------------------------|---------------------------------------|---------------------------------------|--|---------------------------------------|--|--|--|--|--|--|--|---------------------------------------|--|---------------------------------------|---|--|
| 1 Hydrogen 1 H 1.008 | 2 Helium 2 He 4.003 | | | | | | | | | | | 13 Aluminum 13 Al 26.982 | 14 Silicon 14 Si 28.086 | 15 Phosphorus 15 P 30.974 | 16 Sulfur 16 S 32.065 | 17 Chlorine 17 Cl 35.453 | 18 Argon 18 Ar 39.948 | |
| 3 Lithium 3 Li 6.941 | 4 Beryllium 4 Be 9.012 | | | | | | | | | | | 5 Boron 5 B 10.811 | 6 Carbon 6 C 12.011 | 7 Nitrogen 7 N 14.007 | 8 Oxygen 8 O 15.999 | 9 Fluorine 9 F 18.998 | 10 Neon 10 Ne 20.180 | |
| 11 Sodium 11 Na 22.990 | 12 Magnesium 12 Mg 24.305 | 3 Scandium 21 Sc 44.956 | 4 Titanium 22 Ti 47.867 | 5 Vanadium 23 V 50.942 | 6 Chromium 24 Cr 51.996 | 7 Manganese 25 Mn 54.938 | 8 Iron 26 Fe 55.845 | 9 Cobalt 27 Co 58.933 | 10 Nickel 28 Ni 58.693 | 11 Copper 29 Cu 63.546 | 12 Zinc 30 Zn 65.39 | 13 Aluminum 13 Al 26.982 | 14 Silicon 14 Si 28.086 | 15 Phosphorus 15 P 30.974 | 16 Sulfur 16 S 32.065 | 17 Chlorine 17 Cl 35.453 | 18 Argon 18 Ar 39.948 | |
| 19 Potassium 19 K 39.098 | 20 Calcium 20 Ca 40.078 | 21 Scandium 21 Sc 44.956 | 22 Titanium 22 Ti 47.867 | 23 Vanadium 23 V 50.942 | 24 Chromium 24 Cr 51.996 | 25 Manganese 25 Mn 54.938 | 26 Iron 26 Fe 55.845 | 27 Cobalt 27 Co 58.933 | 28 Nickel 28 Ni 58.693 | 29 Copper 29 Cu 63.546 | 30 Zinc 30 Zn 65.39 | 31 Gallium 31 Ga 69.723 | 32 Germanium 32 Ge 72.61 | 33 Arsenic 33 As 74.922 | 34 Selenium 34 Se 78.96 | 35 Bromine 35 Br 79.904 | 36 Krypton 36 Kr 83.80 | |
| 37 Rubidium 37 Rb 85.468 | 38 Strontium 38 Sr 87.62 | 39 Yttrium 39 Y 88.906 | 40 Zirconium 40 Zr 91.224 | 41 Niobium 41 Nb 92.906 | 42 Molybdenum 42 Mo 95.94 | 43 Technetium 43 Tc [98] | 44 Ruthenium 44 Ru 101.07 | 45 Rhodium 45 Rh 102.91 | 46 Palladium 46 Pd 106.12 | 47 Silver 47 Ag 107.87 | 48 Cadmium 48 Cd 112.41 | 49 Indium 49 In 114.82 | 50 Tin 50 Sn 118.71 | 51 Antimony 51 Sb 121.76 | 52 Tellurium 52 Te 127.6 | 53 Iodine 53 I 126.90 | 54 Xenon 54 Xe 131.29 | |
| 55 Cesium 55 Cs 132.91 | 56 Barium 56 Ba 137.33 | 57-70 Lanthanide series | 71 Lanthanum 71 La 138.91 | 72 Cerium 72 Ce 140.12 | 73 Praseodymium 73 Pr 140.91 | 74 Neodymium 74 Nd 144.24 | 75 Promethium 75 Pm [145] | 76 Samarium 76 Sm 150.36 | 77 Europium 77 Eu 151.96 | 78 Gadolinium 78 Gd 157.25 | 79 Terbium 79 Tb 158.93 | 80 Dysprosium 80 Dy 162.50 | 81 Holmium 81 Ho 164.93 | 82 Erbium 82 Er 167.26 | 83 Thulium 83 Tm 168.93 | 84 Ytterbium 84 Yb 173.05 | 85 Francium 85 Fr [223] | 86 Radium 86 Ra [226] |
| 87 Francium 87 Fr [223] | 88 Radium 88 Ra [226] | 89-102 Actinide series | 103 Actinium 103 Ac [227] | 104 Thorium 104 Th 232.04 | 105 Protactinium 105 Pa 231.04 | 106 Uranium 106 U 238.03 | 107 Neptunium 107 Np [237] | 108 Plutonium 108 Pu [244] | 109 Americium 109 Am [243] | 110 Curium 110 Cm [247] | 111 Berkelium 111 Bk [247] | 112 Californium 112 Cf [251] | 113 Einsteinium 113 Es [252] | 114 Fermium 114 Fm [257] | 115 Mendelevium 115 Md [258] | 116 Nobelium 116 No [259] | 117 Tennessine 117 Ts [289] | 118 Oganesson 118 Og [289] |

* Lanthanide series

** Actinide series

| | | | | | | | | | | | | | |
|---------------------------------|-------------------------------|------------------------------------|---------------------------------|---------------------------------|--------------------------------|--------------------------------|----------------------------------|--------------------------------|----------------------------------|----------------------------------|-------------------------------|-----------------------------------|---------------------------------|
| Lanthanum 57 La 138.91 | Cerium 58 Ce 140.12 | Praseodymium 59 Pr 140.91 | Neodymium 60 Nd 144.24 | Promethium 61 Pm [145] | Samarium 62 Sm 150.36 | Europium 63 Eu 151.96 | Gadolinium 64 Gd 157.25 | Terbium 65 Tb 158.93 | Dysprosium 66 Dy 162.50 | Holmium 67 Ho 164.93 | Erbium 68 Er 167.26 | Thulium 69 Tm 168.93 | Ytterbium 70 Yb 173.05 |
| Actinium 89 Ac [227] | Thorium 90 Th 232.04 | Protactinium 91 Pa 231.04 | Uranium 92 U 238.03 | Neptunium 93 Np [237] | Plutonium 94 Pu [244] | Americium 95 Am [243] | Curium 96 Cm [247] | Berkelium 97 Bk [247] | Californium 98 Cf [251] | Einsteinium 99 Es [252] | Fermium 100 Fm [257] | Mendelevium 101 Md [258] | Nobelium 102 No [259] |

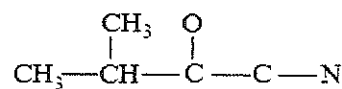
- The valve between a 3.60-L tank containing $\text{O}_2(\text{g})$ at 7.56 atm and a 3.40-L tank containing $\text{Ne}(\text{g})$ at 5.92 atm is opened. Calculate the ratio of partial pressures ($\text{O}_2 : \text{Ne}$) in the container.
A) 1.06 B) 1.28 C) 1.35 D) 0.74 E) 0.56
- At 200 K, the molecules or atoms of an unknown gas, X, have an average velocity equal to that of Ar atoms at 400 K. What is X? (Assume ideal behavior.)
A) He B) CO C) HF D) HBr E) F_2
- At a given temperature, the equilibrium constant K for the reaction $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$ is 3.0×10^9 . If 2.60 mole of SO_2 and 3.90 mole of O_2 are placed in a 1.78-L container and allowed to react to equilibrium at this temperature, what is the concentration of SO_3 at equilibrium?
A) 0.73 M B) 1.46 M C) 2.19 M D) 2.92 M E) 3.65 M
- For carbonic acid (H_2CO_3), $K_{a1} = 4.30 \times 10^{-7}$ and $K_{a2} = 5.62 \times 10^{-11}$. Calculate the pH of a 0.50 M solution of Na_2CO_3 .
A) 2.03 B) 3.33 C) 8.31 D) 10.67 E) 11.97
- You have solutions of 0.200 M HNO_2 and 0.200 M KNO_2 (K_a for $\text{HNO}_2 = 4.00 \times 10^{-4}$). A buffer of pH 3.00 is needed. What volumes of HNO_2 and KNO_2 are required to make 1 L of buffered solution?
A) 500 mL of each B) 286 mL HNO_2 ; 714 mL KNO_2 C) 413 mL HNO_2 ; 587 mL KNO_2
D) 714 mL HNO_2 ; 286 mL KNO_2 E) 587 mL HNO_2 ; 413 mL KNO_2
- The overall K_f for the complex ion $\text{Ag}(\text{NH}_3)_2^+$ is 1.7×10^7 . K_{sp} for AgI is 1.5×10^{-16} . What is the molar solubility of AgI in a solution that is 2.0 M in NH_3 ?
A) 1.3×10^{-3} B) 1.0×10^{-4} C) 8.4×10^{-5} D) 1.5×10^{-9} E) 5.8×10^{-12}

7. For the combustion of ethyl alcohol: $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$ $\Delta H = -1.37 \times 10^3$ kJ, which of the following statements is(are) true?
 I. The reaction is exothermic.
 II. The enthalpy change would be different if gaseous water were produced.
 III. The reaction is not an oxidation-reduction one.
 IV. The products of the reaction occupy a larger volume than the reactants.
 A) I, II B) III, IV C) I, II, III D) II, III, IV E) I, II, III, IV
8. For the reactions $AgI(s) + (1/2)Br_2(g) \rightarrow AgBr(s) + (1/2)I_2(s)$, $\Delta H^\circ = -54.0$ kJ
 ΔH_f° for $AgBr(s) = -100.4$ kJ/mol
 ΔH_f° for $Br_2(g) = +30.9$ kJ/mol
 The value of ΔH_f° for $AgI(s)$ is
 A) +77.3 kJ/mol B) +61.8 kJ/mol C) -61.8 kJ/mol D) -77.3 kJ/mol E) -123.5 kJ/mol
9. For the reaction $A + B \rightarrow C + D$, $\Delta H^\circ = +40$ kJ and $\Delta S^\circ = +50$ J/K. Therefore, the reaction under standard conditions is
 A) spontaneous at temperatures less than 10 K. B) spontaneous at temperatures greater than 800 K
 C) spontaneous only at temperatures between 10 K and 800 K D) spontaneous at all temperatures.
 E) nonspontaneous at all temperatures.
10. When the equation for the following reaction in basic solution is balanced, what is the sum of the coefficients?
 $MnO_4^-(aq) + CN^-(aq) \rightarrow MnO_2(s) + CNO^-(aq)$
 A) 20 B) 13 C) 11 D) 10 E) 8
11. The reduction potentials for Au^{3+} and Ni^{2+} are as follows: $Au^{3+} + 3e^- \rightarrow Au$ $E^\circ = +1.50$ V
 $Ni^{2+} + 2e^- \rightarrow Ni$ $E^\circ = -0.23$ V
 Calculate ΔG° (at 25°C) for the reaction $2Au^{3+} + 3Ni \rightarrow 3Ni^{2+} + 2Au$
 A) +500 kJ B) +1,000 kJ C) -2,140 kJ D) -1,000 kJ E) -500 kJ
12. Consider an atom traveling at 1% of the speed of light. The de Broglie wavelength is found to be 3.31×10^{-3} pm. Which element is this?
 A) He B) F C) P D) Ca E) Br
13. The ionization energy for a hydrogen atom is 1.31×10^6 J/mol. What is the ionization energy for Li^{2+} ?
 A) 1.46×10^5 J/mol B) 4.37×10^5 J/mol C) 1.31×10^6 J/mol D) 3.93×10^6 J/mol E) 1.18×10^7 J/mol
14. Consider the following orderings.
 I. $Al < Si < P < Cl$
 II. $Be < Mg < Ca < Sr$
 III. $I < Br < Cl < F$
 IV. $Na^+ < Mg^{2+} < Al^{3+} < Si^{4+}$
 Which of these give(s) a correct trend in ionization energy?
 A) III only B) I and II C) I and IV D) I, III and IV E) all of them
15. Which atomic species, in its ground state, has six unpaired electrons?
 A) O B) Fe C) Cr D) Cs E) Dy
16. Which of the following series is isoelectronic?
 A) $S^{2-}, Cl^-, K^+, Ca^{2+}$ B) B, C, N, O C) F^-, Cl^-, K^+, Rb^+ D) Na, K, Rb, Cs E) Sn, As, S, F
17. Using the following bond energies:

| | | | | | |
|----------------------|--------------|-----|-----|-----|-----|
| Bond | $C \equiv C$ | C-H | O=O | C=O | O-H |
| Bond Energy (kJ/mol) | 839 | 413 | 495 | 799 | 467 |

 estimate the heat of combustion for 1 mol of acetylene: $C_2H_2(g) + 5/2 O_2(g) \rightarrow 2 CO_2(g) + H_2O(g)$
 A) -1228 kJ B) -447 kJ C) +365 kJ D) +447 kJ E) +1228 kJ

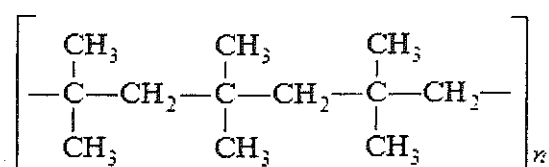
18. Complete the Lewis structure for the following molecule.



How many of the atoms are sp^2 hybridized?

- A) 1 B) 2 C) 3 D) 4 E) 5
19. A first-order reaction is 50% complete at the end of 12 min. What is the value of the rate constant? ($\ln 2 = 0.693$)
A) 0.65 min^{-1} B) 0.33 min^{-1} C) 0.083 min^{-1} D) 0.058 min^{-1} E) 0.042 min^{-1}
20. An X-ray diffraction experiment finds the metal X crystallizes in a face-centered cubic lattice and measures the edge of the unit cell as 409 pm. If the density of the metal X to be 10.5 g/cm^3 , what is X most likely to be?
A) Ag B) Cr C) Pt D) Al E) Pb
21. A 5.96-g sample of a compound is dissolved in 222.0 g of benzene. The freezing point of this solution is 1.06°C below that of pure benzene. What is the molar mass of this compound? (Note: K_f for benzene = $5.12^\circ\text{C}/m$.)
A) 1,300 g/mol B) 556 g/mol C) 285 g/mol D) 180 g/mol E) 130 g/mol
22. What is the expected osmotic pressure, in torr, of a 0.0100 M solution of NaCl in water at 25°C ?
A) 372 torr B) 186 torr C) 93 torr D) 15.6 torr E) 0.245 torr
23. How many different possible trimethylbenzenes exist?
A) 2 B) 3 C) 4 D) 5 E) 6
24. When an organic species is treated with water and H_2SO_4 , a tertiary alcohol is produced. Which of the following structures could represent this compound?
A) $\text{CH}_3\text{CH}=\text{CHCH}_3$ B) $\text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2$ C) $\begin{array}{c} \text{CH}_3-\text{C}=\text{CH}_2 \\ | \\ \text{CH}_3 \end{array}$ D) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$ E) $\begin{array}{c} \text{CH}_3\text{CHCH}=\text{CH}_2 \\ | \\ \text{CH}_3 \end{array}$

25. Consider the polymer drawn below:

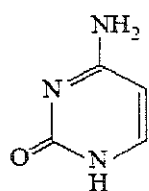


What monomer(s) is (are) needed to produce the above polymer?

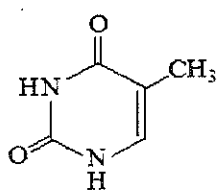
- A) $\text{CH}_2=\text{CH}_2$ and $\text{CH}_3\text{CH}=\text{CH}_2$ B) CO and $\text{CH}_2=\text{CH}_2$ C) $\text{CH}_3\text{CH}=\text{CHCH}_3$
D) $\text{CH}_2=\text{CH}-\text{CH}=\text{CH}_2$ E) $\text{CH}_2=\text{C}(\text{CH}_3)_2$
26. Consider the following sets of quantum numbers. Find the set(s) represent(s) impossible combinations and the incorrect quantum number(s).

| | n | l | m_l | m_s |
|-------|-----|-----|-------|-------|
| Set A | 1 | 1 | 0 | +1/2 |
| Set B | 2 | 0 | 0 | -1/2 |
| Set C | 2 | 1 | -2 | +1/2 |
| Set D | 3 | 1 | -1 | 0 |
| Set E | 3 | 2 | -1 | -1/2 |
| Set F | 4 | 3 | 4 | -1/2 |
| Set G | 5 | 4 | 2 | +1/2 |
| Set H | 8 | 1 | 0 | -1/2 |

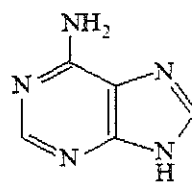
27. Arrange the following compounds in the order of molar solubility (moles per liter) in water at 25°C.
A) CaSO_4 ($K_{sp} = 6.1 \times 10^{-5}$) B) PbSO_4 ($K_{sp} = 1.3 \times 10^{-8}$) C) Ag_3PO_4 ($K_{sp} = 1.8 \times 10^{-18}$)
D) $\text{Sn}(\text{OH})_2$ ($K_{sp} = 3.0 \times 10^{-27}$) E) $\text{Al}(\text{OH})_3$ ($K_{sp} = 2.0 \times 10^{-32}$)
28. Draw the geometric and optical isomers of the complex ion $[\text{Co}(\text{en})_2\text{Cl}_2]^+$. (en = ethylenediamine, $\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2$).
29. Which of the following are polar molecules?
A) SF_2 B) KrF_2 C) BBr_3 D) PBr_3 E) ICl_3 F) XeO_4 G) SiF_4 H) SBr_6
30. Deoxyribonucleic acid (DNA) has a double-helical structure with complementary bases on the two strands. Four nitrogen-containing organic bases existing in DNA are shown below. Which base is always bonded to thymine in DNA double helix? Draw the hydrogen bonding interactions between this complementary pair.



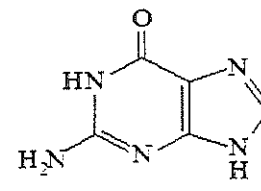
Cytosine (C)



Thymine(T)



Adenine (A)



Guanine (G)