

- 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																	18	
Hydrogen 1 <b>H</b> 1.008																	Helium 2 <b>He</b> 4.003	
Lithium 3 <b>Li</b> 6.941	Beryllium 4 <b>Be</b> 9.012											Boron 5 <b>B</b> 10.811	Carbon 6 <b>C</b> 12.011	Nitrogen 7 <b>N</b> 14.007	Oxygen 8 <b>O</b> 15.999	Fluorine 9 <b>F</b> 18.998	Neon 10 <b>Ne</b> 20.180	
Sodium 11 <b>Na</b> 22.990	Magnesium 12 <b>Mg</b> 24.305											Aluminum 13 <b>Al</b> 26.982	Silicon 14 <b>Si</b> 28.086	Phosphorus 15 <b>P</b> 30.974	Sulfur 16 <b>S</b> 32.065	Chlorine 17 <b>Cl</b> 35.453	Argon 18 <b>Ar</b> 39.948	
Potassium 19 <b>K</b> 39.098	Calcium 20 <b>Ca</b> 40.078	Scandium 21 <b>Sc</b> 44.956	Titanium 22 <b>Ti</b> 47.867	Vanadium 23 <b>V</b> 50.942	Chromium 24 <b>Cr</b> 51.996	Manganese 25 <b>Mn</b> 54.938	Iron 26 <b>Fe</b> 55.845	Cobalt 27 <b>Co</b> 58.933	Nickel 28 <b>Ni</b> 58.693	Copper 29 <b>Cu</b> 63.546	Zinc 30 <b>Zn</b> 65.39	Gallium 31 <b>Ga</b> 69.723	Germanium 32 <b>Ge</b> 72.61	Arsenic 33 <b>As</b> 74.922	Selenium 34 <b>Se</b> 78.96	Bromine 35 <b>Br</b> 79.904	Krypton 36 <b>Kr</b> 83.80	
Rubidium 37 <b>Rb</b> 85.468	Strontium 38 <b>Sr</b> 87.62											Indium 49 <b>In</b> 114.82	Tin 50 <b>Sn</b> 118.71	Antimony 51 <b>Sb</b> 121.76	Tellurium 52 <b>Te</b> 127.6	Iodine 53 <b>I</b> 126.90	Xenon 54 <b>Xe</b> 131.29	
Cesium 55 <b>Cs</b> 132.91	Barium 56 <b>Ba</b> 137.33	* 57-70	Lanthanum 71 <b>Lu</b> 174.97	Cerium 72 <b>Hf</b> 178.49	Praseodymium 73 <b>Ta</b> 180.95	Neodymium 74 <b>W</b> 183.84	Promethium 75 <b>Re</b> 186.21	Samarium 76 <b>Os</b> 190.23	Europium 77 <b>Ir</b> 192.22	Gadolinium 78 <b>Pt</b> 195.08	Terbium 79 <b>Au</b> 196.97	Dysprosium 80 <b>Hg</b> 200.59	Holmium 81 <b>Tl</b> 204.38	Erbium 82 <b>Pb</b> 207.2	Ytterbium 83 <b>Bi</b> 208.98	Lutetium 84 <b>Po</b> [209]	Radium 86 <b>At</b> [210]	Rn
Francium 87 <b>Fr</b> [223]	Radium 88 <b>Ra</b> [226]	** 89-102	Actinium 103 <b>Lr</b> [227]	Thorium 104 <b>Rf</b> [232]	Protactinium 105 <b>Db</b> [231]	Uranium 106 <b>Sg</b> [238]	Neptunium 107 <b>Bh</b> [237]	Plutonium 108 <b>Hs</b> [244]	Americium 109 <b>Mt</b> [243]	Curium 110 <b>Uun</b> [251]	Berkelium 111 <b>Uuu</b> [252]	Californium 112 <b>Uub</b> [257]						

\* Lanthanide series

Lanthanum 57 <b>La</b> 138.91	Cerium 58 <b>Ce</b> 140.12	Praseodymium 59 <b>Pr</b> 140.91	Neodymium 60 <b>Nd</b> 144.24	Promethium 61 <b>Pm</b> [145]	Samarium 62 <b>Sm</b> 150.36	Europium 63 <b>Eu</b> 151.96	Gadolinium 64 <b>Gd</b> 157.25	Terbium 65 <b>Tb</b> 158.93	Dysprosium 66 <b>Dy</b> 162.50	Holmium 67 <b>Ho</b> 164.93	Erbium 68 <b>Er</b> 167.26	Thulium 69 <b>Tm</b> 168.93	Ytterbium 70 <b>Yb</b> 173.04
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\*\* Actinide series

Actinium 89 <b>Ac</b> [227]	Thorium 90 <b>Th</b> 232.04	Protactinium 91 <b>Pa</b> 231.04	Uranium 92 <b>U</b> 238.03	Neptunium 93 <b>Np</b> [237]	Plutonium 94 <b>Pu</b> [244]	Americium 95 <b>Am</b> [243]	Curium 96 <b>Cm</b> [247]	Berkelium 97 <b>Bk</b> [247]	Californium 98 <b>Cf</b> [251]	Einsteinium 99 <b>Es</b> [252]	Fermium 100 <b>Fm</b> [257]	Mendelevium 101 <b>Md</b> [258]	Nobelium 102 <b>No</b> [259]
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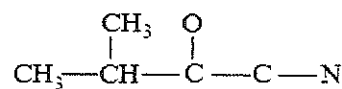
- The valve between a 3.60-L tank containing  $\text{O}_2(\text{g})$  at 7.56 atm and a 3.40-L tank containing  $\text{Ne}(\text{g})$  at 5.92 atm is opened. Calculate the ratio of partial pressures ( $\text{O}_2 : \text{Ne}$ ) in the container.  
A) 1.06                      B) 1.28                      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)  $\text{F}_2$
- 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  $3.0 \times 10^9$ . If 2.60 mole of  $\text{SO}_2$  and 3.90 mole of  $\text{O}_2$  are placed in a 1.78-L container and allowed to react to equilibrium at this temperature, what is the concentration of  $\text{SO}_3$  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 ( $\text{H}_2\text{CO}_3$ ),  $K_{a1} = 4.30 \times 10^{-7}$  and  $K_{a2} = 5.62 \times 10^{-11}$ . Calculate the pH of a 0.50 M solution of  $\text{Na}_2\text{CO}_3$ .  
A) 2.03                              B) 3.33                              C) 8.31                              D) 10.67                              E) 11.97
- You have solutions of 0.200 M  $\text{HNO}_2$  and 0.200 M  $\text{KNO}_2$  ( $K_a$  for  $\text{HNO}_2 = 4.00 \times 10^{-4}$ ). A buffer of pH 3.00 is needed. What volumes of  $\text{HNO}_2$  and  $\text{KNO}_2$  are required to make 1 L of buffered solution?  
A) 500 mL of each                      B) 286 mL  $\text{HNO}_2$ ; 714 mL  $\text{KNO}_2$                       C) 413 mL  $\text{HNO}_2$ ; 587 mL  $\text{KNO}_2$   
D) 714 mL  $\text{HNO}_2$ ; 286 mL  $\text{KNO}_2$                       E) 587 mL  $\text{HNO}_2$ ; 413 mL  $\text{KNO}_2$
- The overall  $K_f$  for the complex ion  $\text{Ag}(\text{NH}_3)_2^+$  is  $1.7 \times 10^7$ .  $K_{sp}$  for  $\text{AgI}$  is  $1.5 \times 10^{-16}$ . What is the molar solubility of  $\text{AgI}$  in a solution that is 2.0 M in  $\text{NH}_3$ ?  
A)  $1.3 \times 10^{-3}$                       B)  $1.0 \times 10^{-4}$                       C)  $8.4 \times 10^{-5}$                       D)  $1.5 \times 10^{-9}$                       E)  $5.8 \times 10^{-12}$

7. For the combustion of ethyl alcohol:  $\text{C}_2\text{H}_5\text{OH}(l) + 3\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(l)$   $\Delta H = -1.37 \times 10^3 \text{ kJ}$ , 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  $\text{AgI}(s) + (1/2)\text{Br}_2(g) \rightarrow \text{AgBr}(s) + (1/2)\text{I}_2(s)$ ,  $\Delta H^\circ = -54.0 \text{ kJ}$   
 $\Delta H_f^\circ$  for  $\text{AgBr}(s) = -100.4 \text{ kJ/mol}$   
 $\Delta H_f^\circ$  for  $\text{Br}_2(g) = +30.9 \text{ kJ/mol}$   
 The value of  $\Delta H_f^\circ$  for  $\text{AgI}(s)$  is  
 A)  $+77.3 \text{ kJ/mol}$               B)  $+61.8 \text{ kJ/mol}$               C)  $-61.8 \text{ kJ/mol}$               D)  $-77.3 \text{ kJ/mol}$               E)  $-123.5 \text{ kJ/mol}$
9. For the reaction  $\text{A} + \text{B} \rightarrow \text{C} + \text{D}$ ,  $\Delta H^\circ = +40 \text{ kJ}$  and  $\Delta S^\circ = +50 \text{ J/K}$ . 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?  
 $\text{MnO}_4^-(aq) + \text{CN}^-(aq) \rightarrow \text{MnO}_2(s) + \text{CNO}^-(aq)$   
 A) 20                      B) 13                      C) 11                      D) 10                      E) 8
11. The reduction potentials for  $\text{Au}^{3+}$  and  $\text{Ni}^{2+}$  are as follows:  $\text{Au}^{3+} + 3e^- \rightarrow \text{Au}$   $E^\circ = +1.50 \text{ V}$   
 $\text{Ni}^{2+} + 2e^- \rightarrow \text{Ni}$   $E^\circ = -0.23 \text{ V}$   
 Calculate  $\Delta G^\circ$  (at  $25^\circ\text{C}$ ) for the reaction  $2\text{Au}^{3+} + 3\text{Ni} \rightarrow 3\text{Ni}^{2+} + 2\text{Au}$   
 A)  $+500 \text{ kJ}$                       B)  $+1,000 \text{ kJ}$                       C)  $-2,140 \text{ kJ}$                       D)  $-1,000 \text{ kJ}$                       E)  $-500 \text{ kJ}$
12. Consider an atom traveling at 1% of the speed of light. The de Broglie wavelength is found to be  $3.31 \times 10^{-3} \text{ pm}$ . Which element is this?  
 A) He                      B) F                      C) P                      D) Ca                      E) Br
13. The ionization energy for a hydrogen atom is  $1.31 \times 10^6 \text{ J/mol}$ . What is the ionization energy for  $\text{Li}^{2+}$ ?  
 A)  $1.46 \times 10^5 \text{ J/mol}$               B)  $4.37 \times 10^5 \text{ J/mol}$               C)  $1.31 \times 10^6 \text{ J/mol}$               D)  $3.93 \times 10^6 \text{ J/mol}$               E)  $1.18 \times 10^7 \text{ J/mol}$
14. Consider the following orderings.  
 I.  $\text{Al} < \text{Si} < \text{P} < \text{Cl}$   
 II.  $\text{Be} < \text{Mg} < \text{Ca} < \text{Sr}$   
 III.  $\text{I} < \text{Br} < \text{Cl} < \text{F}$   
 IV.  $\text{Na}^+ < \text{Mg}^{2+} < \text{Al}^{3+} < \text{Si}^{4+}$   
 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)  $\text{S}^{2-}, \text{Cl}^-, \text{K}^+, \text{Ca}^{2+}$               B) B, C, N, O                      C)  $\text{F}^-, \text{Cl}^-, \text{K}^+, \text{Rb}^+$               D) Na, K, Rb, Cs                      E) Sn, As, S, F
17. Using the following bond energies:  

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

 estimate the heat of combustion for 1 mol of acetylene:  $\text{C}_2\text{H}_2(g) + 5/2 \text{O}_2(g) \rightarrow 2 \text{CO}_2(g) + \text{H}_2\text{O}(g)$   
 A)  $-1228 \text{ kJ}$                       B)  $-447 \text{ kJ}$                       C)  $+365 \text{ kJ}$                       D)  $+447 \text{ kJ}$                       E)  $+1228 \text{ kJ}$

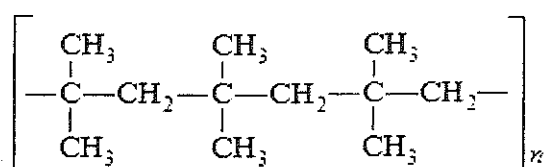
18. Complete the Lewis structure for the following molecule.



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)  $0.65 \text{ min}^{-1}$               B)  $0.33 \text{ min}^{-1}$               C)  $0.083 \text{ min}^{-1}$               D)  $0.058 \text{ min}^{-1}$               E)  $0.042 \text{ min}^{-1}$
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  $10.5 \text{ g/cm}^3$ , 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  $1.06^\circ\text{C}$  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  $25^\circ\text{C}$ ?  
 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  $\text{H}_2\text{SO}_4$ , 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:

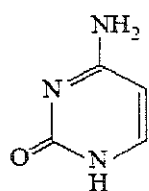


What monomer(s) is (are) needed to produce the above polymer?

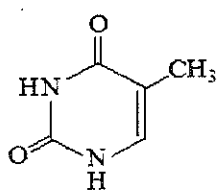
- A)  $\text{CH}_2=\text{CH}_2$  and  $\text{CH}_3\text{CH}=\text{CH}_2$               B)  $\text{CO}$  and  $\text{CH}_2=\text{CH}_2$               C)  $\text{CH}_3\text{CH}=\text{CHCH}_3$   
 D)  $\text{CH}_2=\text{CH}-\text{CH}=\text{CH}_2$                       E)  $\text{CH}_2=\text{C}(\text{CH}_3)_2$
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

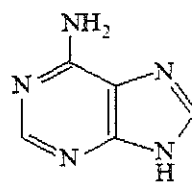
27. Arrange the following compounds in the order of molar solubility (moles per liter) in water at 25°C.  
A)  $\text{CaSO}_4$  ( $K_{sp} = 6.1 \times 10^{-5}$ )      B)  $\text{PbSO}_4$  ( $K_{sp} = 1.3 \times 10^{-8}$ )      C)  $\text{Ag}_3\text{PO}_4$  ( $K_{sp} = 1.8 \times 10^{-18}$ )  
D)  $\text{Sn}(\text{OH})_2$  ( $K_{sp} = 3.0 \times 10^{-27}$ )      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)  $\text{SF}_2$     B)  $\text{KrF}_2$     C)  $\text{BBr}_3$     D)  $\text{PBr}_3$     E)  $\text{ICl}_3$     F)  $\text{XeO}_4$     G)  $\text{SiF}_4$     H)  $\text{SBr}_6$
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.



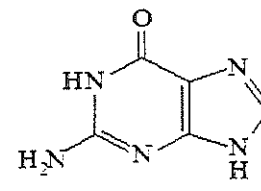
Cytosine (C)



Thymine(T)



Adenine (A)



Guanine (G)