

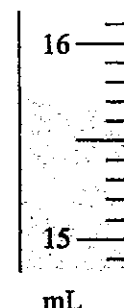
本試題包含三部分（單選題 20 題、多選題 4 題、計算題 2 題），總分 100 分

\*\*\*元素週期表、常用科學常數及公式表位於本試卷末頁\*\*\*

第一部分 單選題（請於答案卷上之「選擇題作答區」作答；每題 3 分；共 60 分）

1. Shown to the right is a schematic diagram of a graduated cylinder. Here, what is the most appropriate reading of the liquid level?

- (A) 15.6 mL  
(B) 15.62 mL  
(C) 15.685 mL  
(D) 15.69 mL  
(E) 15.7 mL

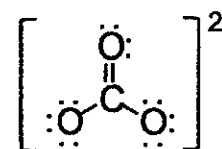


2. Which element has the highest *second ionization energy* ( $IE_2$ )?

- (A) Lithium      (B) Beryllium      (C) Boron  
(D) Carbon      (E) Sodium

3. Regarding the compound shown to the right, which statement is *NOT* correct?

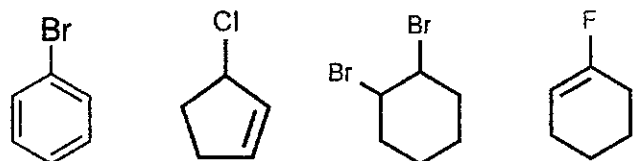
- (A) It can function as a weak Brønsted base  
(B) All four atoms are located on the same plane  
(C) There exist other resonance structure(s)  
(D) Resonance structures transform between each other at a very fast rate  
(E) The three C-O bonds have the same bond length



4. If an alkane has the chemical formula  $C_7H_{16}$ , how many possible structural isomers exist?

- (A) 5      (B) 6      (C) 7      (D) 8      (E) 9

5. How many of the following compounds have *optical isomers*?



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

6. Chlorobenzene and bromobenzene have similar structures and molecular dipole moments. Therefore, these two compounds can form an ideal solution. Given that the vapor pressures of pure chlorobenzene and bromobenzene at  $25^\circ\text{C}$  are  $P_{\text{chlorobenzene}} = 8.8 \text{ Torr}$ ,  $P_{\text{bromobenzene}} = 4.2 \text{ Torr}$ , respectively, calculate the molar fraction of bromobenzene in the vapor phase for a 1:4 chlorobenzene/bromobenzene solution.

- (A) 0.20      (B) 0.34      (C) 0.66      (D) 0.80      (E) 0.86

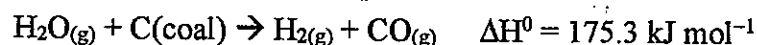
7. When 1.32 g of benzoic acid ( $C_6H_5COOH$ ) is dissolved in 12.52 g of benzene, the freezing point of the solution is determined to be  $3.29^\circ\text{C}$ . The normal freezing point of pure benzene is  $5.50^\circ\text{C}$ , and its molal freezing-point depression constant  $K_f$  is  $5.12 \text{ K kg mol}^{-1}$ . Calculate the molar mass of benzoic acid by *this colligative property method*.

- (A) 61 g/mol      (B) 110 g/mol      (C) 122 g/mol      (D) 220 g/mol      (E) 244 g/mol

8. The thermal decomposition of  $PH_3$  into phosphorus and molecular hydrogen ( $4 PH_3 \rightarrow P_4 + 6 H_2$ ) is a first-order reaction. If the half-life of the reaction is 35.0 seconds at  $680^\circ\text{C}$ , calculate the time required for 90% of the original  $PH_3$  to decompose.

- (A) 5.00 seconds      (B) 96.0 seconds      (C) 108 seconds  
(D) 116 seconds      (E) 173 seconds

9. Water gas is a poisonous, flammable gas mixture comprising carbon monoxide (CO) and hydrogen (H<sub>2</sub>). It can be produced by blowing water vapor over red-hot coal:



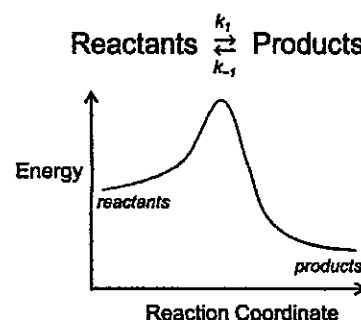
Which of the following statements is correct?

- (A) The reaction is spontaneous below a certain temperature  
 (B) The reaction is spontaneous above a certain temperature  
 (C) The reaction is always spontaneous  
 (D) The reaction is always non-spontaneous  
 (E) The reaction is always at equilibrium
10. Based on the table below, determine the equilibrium constant  $K$  and the reaction enthalpy  $\Delta H$  for the reaction  $\text{A} + \text{B} + 2\text{D} \rightleftharpoons 2\text{E}$ .

Reaction	Equilibrium Constant	Reaction Enthalpy
$\text{A} + \text{B} \rightleftharpoons 2\text{C}$	$K_1$	$\Delta H_1$
$\text{E} \rightleftharpoons \text{C} + \text{D}$	$K_2$	$\Delta H_2$

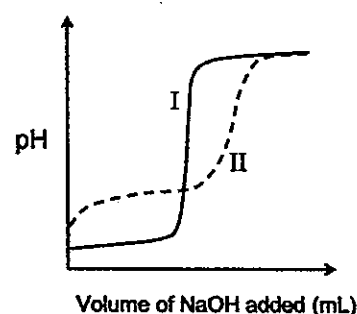
- (A)  $K = K_1/K_2$ ,  $\Delta H = \Delta H_1 - \Delta H_2$       (B)  $K = K_1/K_2^2$ ,  $\Delta H = \Delta H_1 + 2\Delta H_2$   
 (C)  $K = K_1 - K_2$ ,  $\Delta H = \Delta H_1 - 2\Delta H_2$       (D)  $K = K_1/K_2^2$ ,  $\Delta H = \Delta H_1 - 2\Delta H_2$   
 (E)  $K = K_1 - 2K_2$ ,  $\Delta H = \Delta H_1 - 2\Delta H_2$
11. The equilibrium constant  $K_P = 110$  for the following reaction at 400°C:
- $$\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2 \text{HI}(\text{g})$$
- If  $P_{\text{H}_2} = 0.5 \text{ bar}$ ,  $P_{\text{I}_2} = 0.25 \text{ bar}$ ,  $P_{\text{HI}} = 2 \text{ bar}$ , which direction will this reaction go?
- (A) The reaction goes toward products because  $Q < K$   
 (B) The reaction goes toward products because  $Q > K$   
 (C) The reaction goes toward reactants because  $Q < K$   
 (D) The reaction goes toward reactants because  $Q > K$   
 (E) The reaction does not move because the system is already at an equilibrium
12. Phosphoric acid (H<sub>3</sub>PO<sub>4</sub>) is a triprotic acid with  $K_{a1} = 7.5 \times 10^{-3}$ ,  $K_{a2} = 6.2 \times 10^{-8}$ ,  $K_{a3} = 4.8 \times 10^{-13}$ . Calculate the concentration of HPO<sub>4</sub><sup>2-</sup> in a 5.0 M H<sub>3</sub>PO<sub>4</sub> solution.
- (A)  $1.9 \times 10^{-1}$       (B)  $7.5 \times 10^{-3}$       (C)  $6.2 \times 10^{-8}$       (D)  $4.8 \times 10^{-13}$       (E)  $5.3 \times 10^{-14}$
13. Potassium ferricyanide, K<sub>3</sub>[Fe(CN)<sub>6</sub>], exhibits a bright red color and can be used for developing photographic films. What is the oxidation state and the number of  $d$  electrons of Fe in this compound?
- (A) Fe<sup>3+</sup>; 5  $d$  electrons      (B) Fe<sup>3+</sup>; 3  $d$  electrons      (C) Fe<sup>3+</sup>; 6  $d$  electrons  
 (D) Fe<sup>2+</sup>; 6  $d$  electrons      (E) Fe<sup>2+</sup>; 4  $d$  electrons
14. Continuing the previous question, how many unpaired  $d$  electrons are on iron if cyanide is a strong-field ligand?
- (A) 0      (B) 1      (C) 2      (D) 3      (E) 4
15. Which following atomic orbital has the highest number of *radial nodes*?
- (A) 1s      (B) 2p      (C) 3s      (D) 3p      (E) 4d
16. According to quantum mechanics, all properties of a particle confined in a one-dimensional space (coordinate  $x$ ) can be derived from its wavefunction  $\psi(x)$ . Which of the following quantities informs the *probability density* of finding the particle at position  $x_0$ ?
- (A)  $\psi(x_0)$       (B)  $|\psi(x_0)|^2$       (C)  $\left. \frac{d\psi(x)}{dx} \right|_{x=x_0}$   
 (D)  $\left. \frac{d^2\psi(x)}{dx^2} \right|_{x=x_0}$       (E) None of the above

17. If  $\lambda_1$  is the wavelength required to excite an electron in H from 2s to 4p level, what is the wavelength emitted by the same electron when relaxing from 4p back to 1s level?  
(A)  $\lambda_1/5$       (B)  $\lambda_1/4$       (C)  $\lambda_1/2$       (D)  $2\lambda_1$       (E)  $5\lambda_1$
18. Photodissociation of chlorine molecules ( $\text{Cl}_2 + \text{light} \rightarrow 2 \text{Cl}\bullet$ ) creates highly reactive chlorine radicals, which play important roles in chlorination of hydrocarbons, polymerization, and catalyzing the ozone decomposition reaction. According to the molecular orbital theory, what is the lowest-energy excitation pathway (initial MO  $\rightarrow$  final MO) that causes a ground-state  $\text{Cl}_2$  molecule to dissociate? (Assuming the  $\pi_{3p}$  MO's have higher energy than the  $\sigma_{3p}$  MO.)  
(A)  $\sigma_{3s} \rightarrow \pi_{3p}^*$       (B)  $\sigma_{3p} \rightarrow \sigma_{3p}^*$       (C)  $\pi_{3p} \rightarrow \pi_{3p}^*$   
(D)  $\pi_{3p}^* \rightarrow \sigma_{3p}^*$       (E)  $\pi_{3p} \rightarrow \sigma_{3p}^*$
19. Which statement below is *NOT* correct?  
(A) Redox reactions with a positive  $\Delta G^\circ$  would have a negative electromotive force  
(B) The electromotive force reaches a maximum value when the redox reaction is at equilibrium  
(C) The cell voltage of a galvanic cell may change with the ion concentrations in the cell  
(D) Electrolytic cells use electric energy to force non-spontaneous redox reactions to occur  
(E) The electromotive force of a galvanic cell is an intensive property
20. Shown to the right is a reaction coordinate diagram of an elementary reaction. Select the correct statement.  
(A) If the temperature is increased,  $k_1$  will increase, and  $k_{-1}$  will decrease  
(B)  $k_1 > k_{-1}$  because the forward reaction has a higher activation energy  
(C) If the temperature is increased,  $k_1$  will decrease, and  $k_{-1}$  will increase  
(D)  $k_1 = k_{-1}$  when the system reaches equilibrium  
(E) The equilibrium constant  $K = k_1/k_{-1}$



第二部分 多選題 (請於答案卷上之「選擇題作答區」作答; 每題 5 分, 答錯一個選項得 3 分, 答錯兩個選項得 1 分, 答錯 3 個選項以上不給分; 共 20 分)

21. Choose the salt(s) that, when dissolved in water, has  $\text{pH} < 7$  at  $25^\circ\text{C}$ .  
(A) KCl      (B)  $\text{NH}_4\text{Cl}$       (C)  $\text{Fe}(\text{NO}_3)_3$       (D)  $\text{NaNO}_3$       (E)  $\text{NaNO}_2$
22. The titration curves for two acids (I and II, same sample volume) using the same standardized NaOH solution are shown to the right. Select all correct descriptions regarding the comparison between two acids.  
(A) Acid I is the stronger acid  
(B) Acid I has a higher original concentration than acid II  
(C) Both acids are monoprotic  
(D) Acid II can be used to prepare a buffer solution  
(E) When acid II is titrated to the equivalence point at  $25^\circ\text{C}$ , the pH of the solution would be larger than 7
23. What does Maxwell-Boltzmann distribution of molecular speeds inform?  
(A) Through collision with each other, all gas molecules reach the same speed at thermal equilibrium  
(B) For the same molecule, its root mean square (r.m.s.) speed increases with increasing temperature  
(C) At the same temperature, lighter molecules would have higher r.m.s. speed  
(D)  $P(E)$ , the probability of a molecule possessing a certain kinetic energy  $E$ , always decreases with  $E$   
(E) Individual gas molecules do not have the same kinetic energy
24. Which of the following molecule(s) is or are polar?  
(A)  $\text{SO}_2$       (B)  $\text{BeF}_2$       (C)  $\text{C}_2\text{H}_4$       (D)  $\text{H}_2\text{S}$       (E)  $\text{I}_3^-$



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科目：普通化學(C)

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共 4 頁之第 4 頁

第三部分計算題 (請於答案卷上之「非選擇題作答區」依序作答，並標明題號；共 20 分)

25. (10%) The molar solubility of  $Pb(IO_3)_2$  in a 0.10 M  $NaIO_3$  solution is  $2.4 \times 10^{-11} \text{ mol L}^{-1}$  at  $25^\circ\text{C}$ .  
 (25A, 2%) Calculate the solubility product constant ( $K_{sp}$ ) of  $Pb(IO_3)_2$ .  
 (25B, 2%) Calculate the molar solubility of  $Pb(IO_3)_2$  in pure water.  
 (25C, 2%) Calculate the standard Gibbs free energy change ( $\Delta G^0$ ) for the dissolution of  $Pb(IO_3)_2$  in  $H_2O$ .  
 (25D, 4%) Calculate  $[Pb^{2+}]$  and  $[IO_3^-]$  when a chemical equilibrium is reached after mixing 20.0 mL of 0.10 M  $NaIO_3$  with 20.0 mL of 0.025 M  $Pb(NO_3)_2$ .
26. (10%) Redox chemistry  
 (26A, 5%) Balance the following redox reaction under acidic conditions and indicate the oxidizing agent and the reducing agent:  $Cr_2O_7^{2-} + Fe^{2+} \rightarrow Cr^{3+} + Fe^{3+}$  (1)  
 (26B, 2%) Write down the expression of the equilibrium constant  $K_c$  for reaction (1) after balancing.  
 (26C, 3%) The reaction (1) after balancing has a standard electromotive force ( $E^0$ ) of 0.56V. Calculate the value of the equilibrium constant  $K_c$  at  $25^\circ\text{C}$ .

Periodic Table of the Elements

1 IA H Hydrogen 1.008	2 IIA He Helium 4.003																
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305	13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948										
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.29
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71 Lanthanide Series	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [209]	85 At Astatine [209]	86 Rn Radon [222]
87 Fr Francium [223]	88 Ra Radium [226]	89-103 Actinide Series	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [265]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [271]	111 Rg Roentgenium [272]	112 Cn Copernicium [285]	113 Uut Ununtrium [288]	114 Fl Flerovium [289]	115 Uup Ununpentium [288]	116 Lv Livermorium [293]	117 Uus Ununseptium [294]	118 Uuo Oganesson [294]
57 La Lanthanum 138.905	58 Ce Cerium 140.115	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium [145]	62 Sm Samarium 150.36	63 Eu Europium 151.965	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.26	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967			
88 Ac Actinium [227]	89 Th Thorium 232.038	90 Pa Protactinium 231.036	91 U Uranium 238.029	92 Np Neptunium 237.048	93 Pu Plutonium 244.064	94 Am Americium 243.061	95 Cm Curium 247.070	96 Bk Berkelium 247.070	97 Cf Californium 251.080	98 Es Einsteinium [252]	99 Fm Fermium [257]	100 Md Mendelevium [258]	101 No Nobelium [259]	102 Lr Lawrencium [262]			

- Planck constant  $h = 6.62608 \times 10^{-34} \text{ J s}$   
 Rydberg constant  $R_H = 2.180 \times 10^{-18} \text{ J}$   
 Avogadro constant  $N_a = 6.02214 \times 10^{23} \text{ mol}^{-1}$   
 Faraday constant  $F = 96485 \text{ C mol}^{-1}$   
 Ideal gas constant  $R = 0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1} = 62.36 \text{ L torr mol}^{-1} \text{ K}^{-1} = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$

$\Delta G^0 = \Delta H^0 - T\Delta S^0$   
 $\Delta G^0 = -RT \ln K = -nFE^0(\text{cell})$   
 Energy levels of hydrogenic atom:  $E_n = -\frac{Z^2 R_H}{n^2}$   
 Boiling-point elevation:  $T_b - T_b^* = K_b m_B$   
 Freezing-point depression:  $T_f^* - T_f = K_f m_B$   
 First-order reaction:  $[A] = [A]_0 e^{-kt}$   
 Second-order reaction:  $1/[A] = 1/[A]_0 + kt$   
 Arrhenius equation:  $k = Ae^{-E_a/RT}$