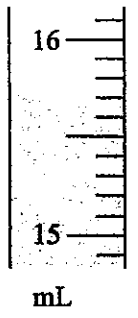
本試題包含三部分（單選題 20 題、多選題 4 題、計算題 2 題），總分 100 分

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）

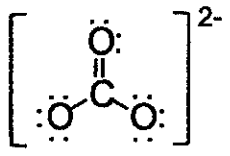
1. Shown to the right is a schematic diagram of a graduated cylinder. Here, what is the most appropriate reading of the liquid level?



(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

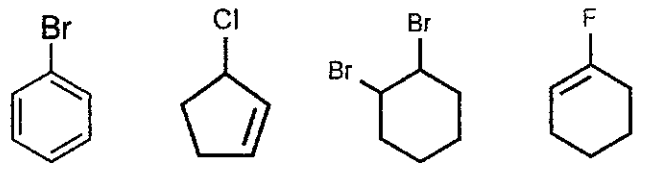
3. Regarding the compound shown to the right, which statement is *NOT* correct?



(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°C are $P_{chlorobenzene} = 8.8$ Torr, $P_{bromobenzene} = 4.2$ 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°C. The normal freezing point of pure benzene is 5.50°C, and its molal freezing-point depression constant K_f is 5.12 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°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

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9. Water gas is a poisonous, flammable gas mixture comprising carbon monoxide (CO) and hydrogen (H_2). It can be produced by blowing water vapor over red-hot coal:

$$H_2O_{(g)} + C(coal) \rightarrow H_{2(g)} + CO_{(g)} \quad \Delta H^0 = 175.3 \text{ kJ mol}^{-1}$$

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 ΔH for the reaction $A + B + 2D \rightleftarrows 2E$.

Reaction	Equilibrium Constant	Reaction Enthalpy
$A + B \rightleftarrows 2C$	K_1	ΔH_1
$E \rightleftarrows C + D$	K_2	ΔH_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:

$$H_2(g) + I_2(g) \rightleftarrows 2\,HI(g)$$

If $P_{H2} = 0.5$ bar, $P_{I2} = 0.25$ bar, $P_{HI} = 2$ 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_3PO_4) 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_4^{2-} in a 5.0 M H_3PO_4 solution.

(A) 1.9×10^{-1} (B) 7.5×10^{-3} (C) 6.2×10^{-8} (D) 4.8×10^{-13} (E) 5.3×10^{-14}

13. Potassium ferricyanide, $K_3[Fe(CN)_6]$, 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^{3+}; 5 *d* electrons (B) Fe^{3+}; 3 *d* electrons (C) Fe^{3+}; 6 *d* electrons
(D) Fe^{2+}; 6 *d* electrons (E) Fe^{2+}; 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) 1*s* (B) 2*p* (C) 3*s* (D) 3*p* (E) 4*d*

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

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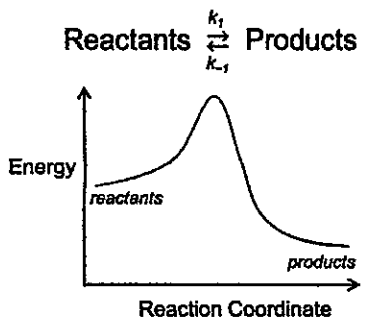
17. If λ_1 is the wavelength required to excite an electron in H from 2*s* to 4*p* level, what is the wavelength emitted by the same electron when relaxing from 4*p* back to 1*s* level?
(A) $\lambda_1/5$ (B) $\lambda_1/4$ (C) $\lambda_1/2$ (D) $2\lambda_1$ (E) $5\lambda_1$

18. Photodissociation of chlorine molecules (Cl_2 + light → 2 Cl•) 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 → final MO) that causes a ground-state Cl_2 molecule to dissociate? (Assuming the π_{3p} MO's have higher energy than the σ_{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 ΔG^0 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

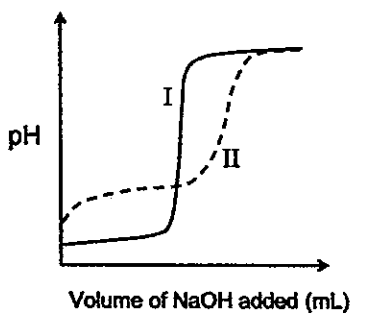
20. Shown to the right is a reaction coordinate diagram of an elementary reaction. Select the correct statement.
(A) If the temperature is increased, k_1 will increase, and k_{-1} will decrease
(B) $k_1 > k_{-1}$ because the forward reaction has a higher activation energy
(C) If the temperature is increased, 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 pH < 7 at 25°C.
(A) KCl (B) NH_4Cl (C) $Fe(NO_3)_3$ (D) $NaNO_3$ (E) $NaNO_2$

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°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) SO_2 (B) BeF_2 (C) C_2H_4 (D) H_2S (E) I_3^-

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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 2.4×10^{-11} mol L^{-1} at 25°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 (ΔG^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 $Pb(NO_3)_2$.

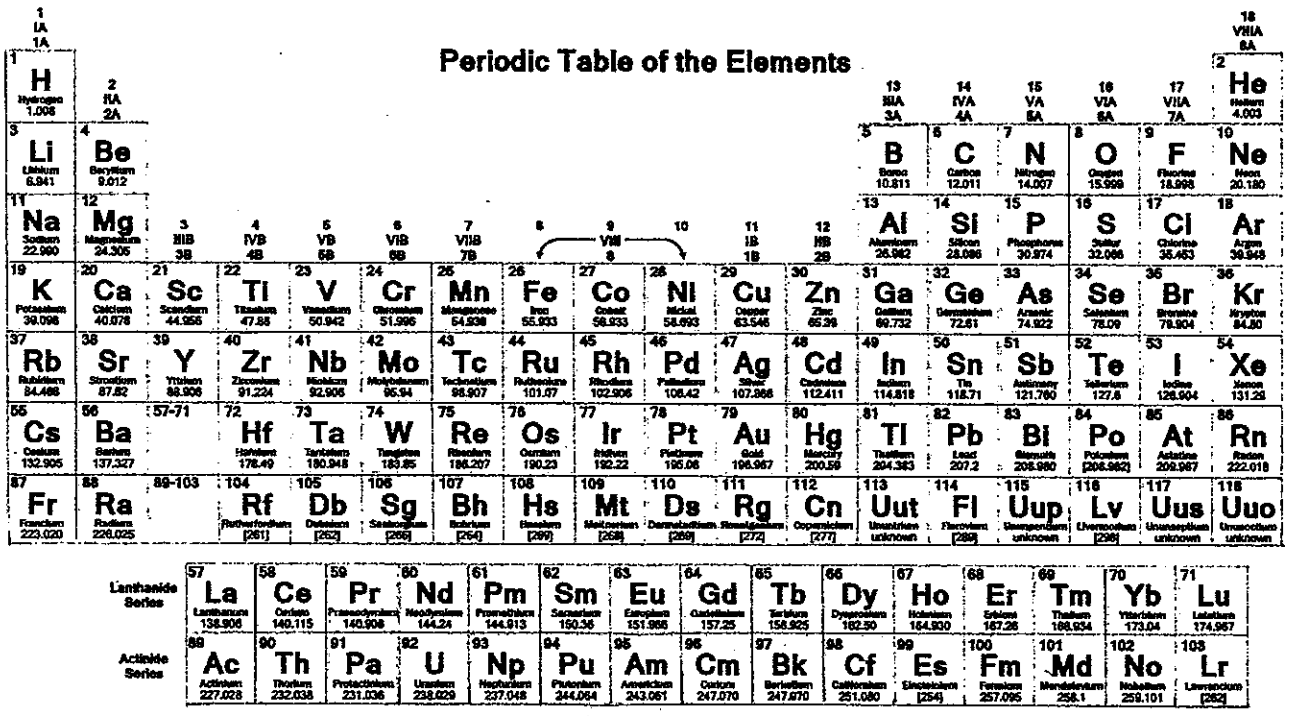
26. (10%) Redox chemistry

(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°C.

Periodic Table of the Elements



Planck constant $h = 6.62608 \times 10^{-34}$ J s

Rydberg constant $R_H = 2.180 \times 10^{-18}$ J

Avogadro constant $N_a = 6.02214 \times 10^{23}$ mol^{-1}

Faraday constant $F = 96485$ C mol^{-1}

Ideal gas constant $R = 0.08206$ L atm mol^{-1} K^{-1} = 62.36 L torr mol^{-1} K^{-1} = 8.314 J mol^{-1} K^{-1}

$\Delta G^0 = \Delta H^0 - T\Delta S^0$

$\Delta G^0 = -RT\ln K = -nFE^0(cell)$

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: $k = Ae^{-E_a/RT}$

試題隨卷繳回