

Physical Chemistry

物理化學

物理常數

$$\begin{array}{lll} h = 6.626 \times 10^{-34} \text{ J}\cdot\text{s} & e = 1.602 \times 10^{-19} \text{ C} & m_e = 9.109 \times 10^{-31} \text{ kg} \\ c = 2.998 \times 10^8 \text{ m s}^{-1} & 4\pi\epsilon_0 = 1.113 \times 10^{-10} \text{ J}^{-1} \text{ C}^2 \text{ m}^{-1} & 1 \text{ cal} = 4.184 \text{ J} \\ L = 6.022 \times 10^{23} \text{ mol}^{-1} & k_B = 1.381 \times 10^{-23} \text{ J K}^{-1} & \text{amu} = 1.66054 \times 10^{-27} \text{ kg} \\ R = 8.314 \text{ J mol}^{-1} \text{ s}^{-1} = 0.0821 \text{ liter atm mol}^{-1} \text{ K}^{-1} & & \ln 10 = 2.303 \end{array}$$

單選題 (每題二分，共五十分)

1. A 500-W sodium-vapor lamp emits yellow light of wavelength 590 nm. The number of photons emitted per second is:
(A) 1.2×10^5 (B) 3.0×10^{20} (C) 1.5×10^{21} (D) 5.1×10^{23} (E) 9.5×10^{27}
2. What is the molar heat capacity of helium gas at room temperatures?
(A) 8.314 J/K (B) 20.8 J/K (C) 4.185 J/K (D) 25.0 J/K (E) 12.5 J/K
3. The vibrational frequency of H_2 molecule is 4400 cm^{-1} . What is the vibrational frequency (in cm^{-1}) of D_2 molecule?
(A) 550 (B) 2200 (C) 3100 (D) 3600 (E) 6200
4. Which of the following molecule is paramagnetic in its electronic ground state?
(A) C_2 (B) N_2 (C) H_2 (D) O_2 (E) CO.
5. According to thermodynamics, which of the following is not a spontaneous reaction?
(A) burning of fuel (B) electron ionization of a sodium atom (C) oxidation of iron in air
(D) diffusion of gas to vacuum (E) precipitation from an over-saturated solution
6. How many vibrational modes are there for an HCN molecule?
(A) 2 (B) 3 (C) 4 (D) 5 (E) 6
7. Which of the following gas-phase molecule cannot readily be identified by an IR spectrometer?
(A) H_2 (B) CO (C) CH_4 (D) HCN (E) F_2
8. What is the ground-state term symbol for the carbon atom?
(A) $^2\text{P}_{1/2}$ (B) $^2\text{P}_{3/2}$ (C) $^3\text{P}_2$ (D) $^3\text{P}_1$ (E) $^3\text{P}_0$

9. A wooden artifact from a Chinese temple has a ^{14}C activity of 7.9 counts per minute as compared with an activity of 31.7 counts per minute for a standard of zero age. From the half-life for ^{14}C decay, 5730 years, what is the approximate age (in years) of the artifact?
(A) 1850 (B) 2900 (C) 5730 (D) 11500 (E) 22920
10. What is the de Broglie wavelength (in \AA) of an electron moving at a speed of $1.0 \times 10^6 \text{ m s}^{-1}$.
(A) 4100 (B) 25 (C) 16 (D) 10 (E) 7.3
11. Which of the following is *not* a correct approximation to the electronic wavefunction for the excited helium atom $1s^1 2s^1$?
(A) $[1s(1)2s(2) + 1s(2)2s(1)] [\alpha(1)\beta(2) + \alpha(2)\beta(1)]$
(B) $[1s(1)2s(2) - 1s(2)2s(1)] \alpha(1)\alpha(2)$
(C) $[1s(1)2s(2) + 1s(2)2s(1)] [\alpha(1)\beta(2) - \alpha(2)\beta(1)]$
(D) $[1s(1)2s(2) - 1s(2)2s(1)] \beta(1)\beta(2)$
(E) $[1s(1)2s(2) - 1s(2)2s(1)] [\alpha(1)\beta(2) + \alpha(2)\beta(1)]$
12. Comparing the following energies in magnitude (1) ionization energy of He atom (2) ionization energy of H atom (3) hydrogen bonding in water dimer (4) vibrational zero-point energy of CH_4 (5) average rotational energy of benzene at room temperature
(A) (2) > (1) > (3) > (4) > (5) (B) (1) > (2) > (4) > (3) > (5) (C) (1) > (2) > (3) > (5) > (4)
(D) (1) > (2) > (5) > (3) > (4) (E) (2) > (3) > (1) > (4) > (5)
13. A first-order chemical reaction has a rate constant of 700.0 s^{-1} . Assuming that the rate of the reverse reaction is negligible, how long (in s) does it take for the reaction to be over 85% but less than 90% completion? ($\ln 2 = 0.693$, $\ln 3 = 1.099$)
(A) 7.0×10^{-4} (B) 1.0×10^{-3} (C) 2.1×10^{-3} (D) 3.0×10^{-3} (E) 5×10^{-3}
14. Sirius, one of the hottest known star, has approximately a blackbody spectrum with $\lambda_{\text{max}} = 260 \text{ nm}$. From the Wein displacement law $\lambda_{\text{max}} T \cong hc/5k$, find the surface temperature (in K) of Sirius.
(A) 11000 (B) 9000 (C) 6000 (D) 4000 (E) 3000
15. The work done by an isothermal reversible expansion of 1 mole of ideal gas to 2.72 times its initial volume at 300 K is:
(A) 0.0 kJ (B) 1.73 kJ (C) 2.49 kJ (D) 4.99 kJ (E) 6.78 kJ
16. From the above question, what is the internal energy change of the gas in the process?
(A) 8.31 kJ (B) 4.16 kJ (C) 2.08 kJ (D) 1.04 kJ (E) 0 kJ

17. If a reaction has an activation energy of 25 kJ/mol, how many times the rate constant would increase from 300 K to 600 K?
(A) 50 (B) 150 (C) 300 (D) 500 (E) 800
18. What is the molar volume (in liter) of Ne gas at 500 K, 2 atm?
(A) 22.4 (B) 20.5 (C) 18.0 (D) 12.7 (E) 6.4
19. Which of the following molecule has a pure rotational spectrum?
(A) CH₄ (B) N₂ (C) BH₃ (D) CO (E) CO₂
20. If a unimolecular reaction has an equilibrium constant of 10 at 300 K, what is the standard Gibbs free energy of reaction?
(A) -5.7 kJ/mol (B) -2.4 kJ/mol (C) 0.0 kJ/mol (D) 2.4 kJ/mol (E) 5.7 kJ/mol
21. Which one of the following gas molecules has the lowest mean velocity at room temperature?
(A) CO₂ (B) F₂ (C) Cl₂ (D) C₄H₁₀ (E) O₃
22. A heat engine operates between two temperatures, 550 °C and 40 °C. What is its maximum efficiency according to the second law of thermodynamics?
(A) 7% (B) 15% (C) 23% (D) 38% (E) 62%
23. What is the orbital angular momentum for an electron in a 3d orbital of a hydrogen atom?
(A) 0 \hbar^2 (B) 1 \hbar^2 (C) 2 \hbar^2 (D) 4 \hbar^2 (E) 6 \hbar^2
24. The ground-state term symbol for the electron configuration 3d⁹ is:
(A) ¹S (B) ²G (C) ²D (D) ²P (E) ⁴F
25. A particle of mass m in a one-dimensional box of length L , what is the energy difference (in $\hbar^2 m^{-1} L^{-2}$) between the two lowest energy levels?
(A) 1/2 (B) 3/2 (C) 1/8 (D) 3/8 (E) 5/8

分析化學 (50 分)

一、單選題 (每題三分)

- (1) Which of the following statement is CORRECT?
 - (A) Visible absorption spectroscopy is a direct and rapid method to determine vibrational energy levels of organic molecules.
 - (B) Inductively coupled plasma mass spectrometry (ICP-MS) is a direct and rapid method to identify electronic transition energy levels.
 - (C) Infra red spectroscopy is a direct and rapid method to determine rotational energy levels of organic molecules.
 - (D) Matrix assisted laser desorption ionization mass spectrometry (MALDI-MS) is a direct and rapid method to determine rotational energy levels of organic molecules.
 - (E) None of the above

- (2) Which of the following analytical tool(s) can be used to determine protein molecular weights?
 - (A) Static light scattering spectroscopy
 - (B) Electron impact (EI) ionization mass spectrometry
 - (C) Gas chromatography
 - (D) Isotachopheresis
 - (E) All of the above

- (3) When a recorded spectrum has the signal-to-noise ratio 3, please calculate the signal-to-noise ratio for the average of 16 spectra recorded in the same manner.
 - (A) 108
 - (B) 36
 - (C) 18
 - (D) 12
 - (E) 3

- (4) Please calculate the pH value of the following solution system: diprotic acid H_2A (100 mL, 0.1 M) of which k_1 and k_2 are 10^{-4} and 10^{-10} M respectively, mixed with NaOH (5 mL, 1M)
 - (A) 3
 - (B) 4
 - (C) 5
 - (D) 7
 - (E) 9

- (5) Please calculate the pH value at the equivalence point when a dilute weak acidic solution (100 mL; 0.1 M) is titrated with NaOH (1M) when the dissociation constant of this weak acid is

10^{-6} M.

(A) 3

(B) 4

(C) 5

(D) 6

(E) None of the above

- (6) When the measurement bias of a standard sample using a new method is acceptable but nearly unacceptable at 99% confidence level, in which confidence level this method will be acceptable?
- (A) 99.9%
(B) 98 %
(C) 97.5%
(D) 96%
(E) 90%

二、問答題（每題四分）

- (7) What is enzyme-linked immunosorbent assay (ELISA)?
- (8) Derive the solubility product constant (K_{sp}) expression equations in terms of their solubility (s) for the following slightly soluble salts MX and M_2Y , respectively.
- (9) Is cyclic voltammetry (CV) an amperometric or potentiometric method?

三、計算題（每題十分）

- (10) There are two chromatographic peaks of which the base-line widths are both 1 min.
- (a) When the retention times of these two peaks are 6 and 8 min, respectively, please estimate the resolution of these two peaks. (五分)
- (b) When the capacity factor (k') of the first peak is 1, please estimate the retention time of injection solvent. (五分)
- (11) The Wien displacement law states that the wavelength maximum (λ_{max}) in micrometers for blackbody radiation is
- $$\lambda_{max}T = 2.90 \times 10^3$$
- where T is the temperature in Kelvin's. Calculate the λ_{max} of a tungsten filament bulb operated under 2870 and 3000 K.