## 本節考題分兩部分：第一部分 物理化學 及 第二部分 分析化學

## 第一部分 物理化學

### 壹：物理化學（50 分）

### Physical Chemistry

單選題（每題 2.5 分，共 50 分）

1. Which of the following observations can be explained by classical physics:
   (a) black-body radiation (b) heat capacities (c) atomic spectra
   (d) molecular spectra (e) none.
2. Which of the following statements are wrong concerning a particle in a box of length L:
   (a) the energy is not quantized;
   (b) the energy is proportional to $L^{-2}$;
   (c) the average value of its linear momentum is 0;
   (d) the first excitation energy of a proton confined to a one-dimensional infinite square well with length of $1\times10^{-15}$m is $0.6\times10^{9}$ eV.
   (e) None.
3. Helium is a monatomic gas. What is its approximate molar heat capacity at constant pressure?
   (a) 8.314J/K (b) 20.8J/K (c) 4.185 J/K (d)12.5 J/K (e) 0.082 J/K
4. Which of the following gas molecules have the highest mean velocity at room temperature?
   (a) $CO_2$ (b) $O_2$ (c) $H_2O$ (d) $CI_2$ (e) $NH_3$.
5. A sodium lamp emits yellow light at 550nm. What is the frequency of the yellow light? (speed of light $=2.998\times10^{8}ms^{-1}$)
   (a) $5.45\times10^{14}s^{-1}$ (b) $5.45\times10^{11}s^{-1}$ (c) $1.65\times10^{2}s^{-1}$ (d) $1.65\times10^{5}s^{-1}$
   (e) $1.82\times10^{6}s^{-1}$
6. A heat engine operates between two temperatures, 600 K and 300 K. What is its maximum efficiency according to the second law of thermodynamics?
   (a) 50% (b) 94% (c) 66% (d) 48% (e) 34%
7. The number of vibrational normal modes of $H_2O$ is:
   (a) 9 (b) 6 (c) 3 (d) 4 (e) 5.
8. One mole of liquid water at 100℃ is in equilibrium with vapor at 1 atm pressure. If the enthalpy change associated with vaporization of liquid water at 100℃ is 40.6kJ/mol, what is $\Delta G$ of the process?
   (a) 40.6 kJ (b) 406 kJ (c) 0.0 kJ (d) 8.314 kJ (e) 22.4 kJ.
9. The rate constant of a reaction increases 10 times from 300 K to 400 K, what is the activation energy of the reaction? (1n 10＝2.303)
   (a) 0.23 kJ/mol (b) 2.3 kJ/mol (c) 23 kJ/mol (d) 230 kJ/mol
   (e) 11.5 kJ/mol
10. The fundamental frequency of hydrogen molecule is $4159cm^{-1}$. What is the force constant of the H-H bond? (1 amu $=1.66\times10^{-27}$ kg)
    (a) 509 N/m (b) 2080 N/m (c) 320 N/m (d) 1006 N/m (e) 254 N/m

11. What is the de Broglie wavelength of a neutron a translational kinetic energy equal to kT at 300 K.
(a) 0.0178 cm (b) $1.78\times10^{-7}$ m (c) $178\times10^{-12}$ m (d) $178\times10^{-15}$ m
(e) $178\times10^{-17}$ m (Planck constant = 6.626 $10^{-34}$ Js)
12. What is the ground-state term symbol for the boron atom?
(a) $^2P_{1/2}$ (b) $^2P_{3/2}$ (c) $^3P_2$ (d) $^1S_0$ (e) $^2D_{3/2}$
13. Which of the following is a correct approximation to the electronic wave function for helium atom?
(a) 1s(1)1s(2) [α(1)β(2)−α(2)β(1)]
(b) 1s(1)1s(2) α(1)α(2)
(c) 1s(1)1s(2) α(1)β(2)
(d) 1s(1)2s(2) α(1)α(2)
(e) 1s(1)2s(2) α(1)β(2)
14. Which of the following molecule has a pure rotational spectrum?
(a) NO (b) $CH_4$ (c) $BF_3$ (d) $C_6H_6$ (e) $CO_2$
15. Comparing the following energies in magnitude (1) ionization energy of H atom (2) bond energy of $O_2$ molecule (3) lowest electronic excited state energy of benzene (4) vibrational zero-point energy of $H_2O$ (5) hydrogen bonding in HF dimmer.
(a) (2)>(1)>(4)>(3)>(5) (b) (3)>(1)>(2)>(5)>(4)
(c) (1)>(2)>(4)>(3)>(5) (d) (2)>(3)>(1)>(5)>(4)
(e) (1)>(2)>(3)>(4)>(5)
16. The number of pentagons in a fullerene $C_{60}$ is:
(a) 12 (b) 15 (c) 10 (d) 20 (e) 32
17. What is the point group of $C_{60}$?
(a) $T_d$ (b) $O_h$ (c) O (d) $I_h$ (e)$D_{5h}$
18. A wooden artifact from a Chinese temple has a $^{14}C$ activity of 22.4 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 of the artifact?
(a) 2865 years (b) 11460 years (c) 1430 years (d) 1910 years (e) 5730 years.
19. A first-order chemical reaction has a rate constant of $300.0s^{-1}$. Assuming that the rate of the reverse reaction is negligible, how long does it take for the reaction to be just over 95% complete? (log 2=0.301, log 3=0.477, ln 2=0.693, ln 3=1.099)
(a) 2.31 (b) $2.31\times10^{-2}$ (c) $9.24\times10^{-3}$s (d) $2.31\times10^{-3}$s (e) $6.93\times10^{-3}$s
20. Which of following process is the fastest on average?
(a) intersystem crossing (b) molecular rotation (c) vibrational relaxation
(d) diffusion in liquid (e) crystallization in supersaturated solution

## 第二部分 分析化學

# 貳、分析化學（50 分）

一、單選題（每題三分）

(21) Which of the following is the correct ratio of the number of moles of ferrous ion ($Fe^{2+}$) to the number of moles of permanganate ion ($MnO_4^-$), when $Fe^{2+}$ is completely reacted with $MnO_4^-$? (moles of $Fe^{2+}$/ moles of $MnO_4^-$)

(A) 1

(B) 0.5

(C) 0.2

(D) 0.4

(E) 5

(22) Which of the following statement is CORRECT to decrease the retention time of a solute on a gas chromatography column?

(A) decreasing the column temperature

(B) increasing the column length

(C) replacing the stationary phase with one in which the solute posses a larger partition coefficient.

(D) all of the above

(E) none of the above

(23) For separating and measuring the compounds of high molecular weight, which of the following is an advantage(s) of high performance liquid chromatography (HPLC) over gas chromatography (GC)?

I. in HPLC preparing vaporizable derivatives is not necessary

II. HPLC column is more affordable

III. HPLC detector becomes more sensitive as the compound molecular weight increase

(A) I

(B) II

(C) III

(D) I and II

(E) I and III

(24) Which of the following statement is CORRECT

(A) Visible absorption spectroscopy is a direct and rapid method to determine rotational energy levels of organic molecules.

(B) Atomic absorption spectroscopy is a direct and rapid method to identify organic functional group.

(C) Infrared spectroscopy is a direct and rapid method to identify organic functional group.

(D) Electron spin resonance spectroscopy is a direct and rapid method to determine rotational energy levels of organic molecules.

(E) None of the above

(25) Which of the following statement is CORRECT
(A) Rotational (rigid rotor) energy levels are evenly separated.
(B) Vibrational (harmonic oscillator) energy levels are evenly separated
(C) Electronic (Born-Oppenheimer approximation) energy levels are evenly separated.
(D) All of the above
(E) None of the above

(26) The solubility product constant of a slightly solute salt $MX_2$ can be expressed as
(A) $[M^{2+}][X^-]$
(B) $[M^{2+}]^2[X^-]$
(C) $[M^{2+}][X^-]^2$
(D) $[M^{2+}]^2[X^-]^2$
(E) None of the above

(27) A high performance liquid chromatography does NOT have the following component(s) which a gas chromatography has.
I. stationary phase
II. detector
III. device for temperature programming
(A) I
(B) II
(C) III
(D) I and II
(E) I and III

(28) In a mass spectrometer ions are separated due to
I. size of the ions
II. mass-to-charge ratio of the ions
III. number of ions
(A) I
(B) II
(C) III
(D) I and II
(E) I and III

(29) Which of the following statement is CORRECT
(A) The ionic strength of a solution depends on the charges of the ions
(B) The ionic strength of a solution does NOT depend the concentration of the ions
(C) The ionic strength of a solution depends on the sizes of the ions
(D) All the above
(E) None of the above

(30) Which of the following are able to influence the retention time of an analyte in a high performance liquid chromatography column

I. column length
II. detector wavelength
III. mobile phase composition

(A) I
(B) II
(C) III
(D) I and II
(E) I and III

二、簡答題（無須計算過程；每題四分）

(31) When the reduction potential of an electrode determined relative to a saturated calomel electrode is -0.70 volt, what is the reduction potential of this same electrode relative to the standard hydrogen electrode?

[Hint: the reduction potentials of a saturated calomel electrode and a standard hydrogen electrode are +0.24 and 0.0 volt respectively.]

(32) When a recorded spectrum has the signal-to-noise ratio 4, please calculate the signal-to-noise ratio for the average of 25 spectra recorded in the same mannered.

(33) Please calculate the pH value of the following solution system: diprotonic acid $H_2A$ (100 mL, 0.1 M) of which $k_1$ and $k_2$ are $10^{-5}$ and $10^{-13}$ M respectively, mixed with NaOH (10 mL, 1M)

三、問答題（每題四分）

Answer the following questions regarding mass spectrometry.

(34) Please illustrate two types of molecular ionization processes occurring at ambient pressure.

(35) Explain why liquid chromatography can be connected with the above ionization sources in a straightforward manner?