

※請將選擇題作答於試卷內之「選擇題作答區」。

Speed of light in vacuum	$2.9979 \times 10^8 \text{ m s}^{-1}$
Planck constant	$6.626 \times 10^{-34} \text{ J s}$
Boltzmann constant	$1.38 \times 10^{-23} \text{ J K}^{-1}$
Electron charge	$1.602 \times 10^{-19} \text{ C}$
Proton mass	$1.67 \times 10^{-27} \text{ kg}$
Avogadro constant	$6.02 \times 10^{23} \text{ mol}^{-1}$

Section A : (48% , 單選題 , 每題答對 4 分)

- Which of the following statements is a WRONG description of the ideal gas model?
  - There is no interaction among the gas molecules
  - The collision between two gas molecules is totally elastic
  - The volume of each gas molecule is perfectly spherical
  - Each molecule is undergoing linear motion between collisions
  - Dalton's law is obeyed
- Calculate the molarity of pure water.
 

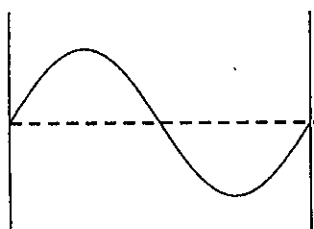
A. 55.6 M      B. 1.0 M      C. 10 M      D. 5.6 M      E. 27.8 M
- Consider a mineral salt perovskite  $\text{MgSiO}_3$ . If some of the Si atoms are substituted by Al, determine the value  $x$  for the resultant non-stoichiometric perovskite compound  $\text{MgSi}_{0.95}\text{Al}_{0.05}\text{O}_x$ .
 

A. 2.9      B. 2.975      C. 2.95      D. 3      E. 3.25
- Suppose a rock contains 0.115 mg of  $^{206}\text{Pb}$  and 1.000 mg of  $^{238}\text{U}$ . Assume that all  $^{206}\text{Pb}$  is due to the radioactive decay of  $^{238}\text{U}$ , which has a half-life of  $4.5 \times 10^9$  years. Calculate the age of the rock.
 

A.  $8.1 \times 10^8$  years      B.  $8.1 \times 10^7$  years      C.  $8.1 \times 10^6$  years  
D.  $8.1 \times 10^5$  years      E.  $8.1 \times 10^4$  years

見背面

- 5 Referring to the following wavefunction calculated for a particle in a one-dimensional box.



The probability that a particle will appear in the middle of the box will be

- A. 1.0      B. 0      C. 0.25      D. 0.5      E. 0.1
- 6 For a solution of 34 wt% HNO<sub>3</sub>, calculate the molarity of the acid if the density of the solution is identical to pure water.  
A. 8 M      B. 6.1 M      C. 7.1 M      D. 5.4 M      E. 3.4 M
- 7 Which of the following compound does NOT have sp<sup>2</sup> hybrid orbitals?  
A. diamond      B. graphite      C. benzene      D. C<sub>2</sub>H<sub>4</sub>      E. ethene
- 8 An electrolysis cell (volume 1.0 L) containing 0.025 M of Mn<sup>2+</sup> and another metal ion (M<sup>3+</sup>) is fitted with Mn and Pt electrodes. Suppose the reactions at the electrodes are  

$$\text{Mn}_{(s)} \rightarrow \text{Mn}^{2+} + 2e^{-}$$

$$\text{M}^{3+} + 3e^{-} \rightarrow \text{M}_{(s)}$$
 If a constant current of 2.60 A is passed through the cell for 18.0 min, 0.504 g of the metal (M) will plate out on the Pt electrode. What is the atomic weight of M?  
 A. 23.0 g/mol      B. 42.0 g/mol      C. 46.0 g/mol      D. 56.0 g/mol      E. 52.0 g/mol
- 9 For a [H<sup>+</sup>] concentration of 0.020 M, the pH value should read  
 A. 1.6990      B. 1.699      C. 1.7      D. 1.70      E. -1.7
- 10 Which of the following statement is CORRECT?  
 A. Orbital means electron density  
 B. For orbitals with the same *l* quantum number (same shape), the smaller the orbital, the higher the energy  
 C. Experimentally we can measure the shape of an orbital  
 D. The 2s and 2p orbitals are degenerate for a carbon atom  
 E. The 3s orbital has two nodes in its radial probability

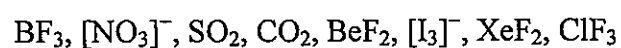
題號： 21  
科目：普通化學(A)

題號： 21  
共 5 頁之第 3 頁

11 The compound  $\text{GeH}_3\text{COOH}$  is an unstable weak acid. At room temperature, a 0.050 M solution of  $\text{GeH}_3\text{COOH}$  has a pH of 2.42. Determine the  $K_a$  of  $\text{GeH}_3\text{COOH}$ .

- A. 2.42      B.  $3.8 \times 10^{-3}$       C.  $3.1 \times 10^{-4}$       D. 0.38      E. 3.81

12 Consider the following molecules and ions:

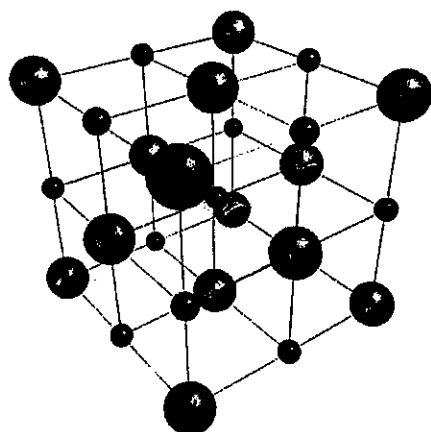


Which of the following descriptions are correct?

- A. There are four linear molecules/ions  
B.  $[\text{NO}_3]^-$  has three isolable resonance structures.  
C.  $\text{BF}_3$ ,  $\text{BeF}_2$ ,  $\text{XeF}_2$  and  $\text{ClF}_3$  are non-polar molecules  
D. All of the non-polar molecules contain non-polar bonds  
E. None of the above

Section B : (12% , 複選題 , 每題全部答對 4 分 , 答錯一選項或以上者 0 分)

13 Which of the following statements regarding the NaCl crystal structure are correct:



- A. The structure is face-centered cubic lattice  
B. The cation coordination number is 6  
C. The anion coordination number is 6  
D. There are four  $\text{Na}^+$  ions per unit cell  
E. There are 12  $\text{Cl}^-$  ions per unit cell

見背面

- 14 Lithium metal, which has a work function of 279.7 kJ/mol, was used in photoelectric effect study. Which of the following statements are correct?
- A. The energy of each incident photon must be higher than  $4.646 \times 10^{-19}$  J to eject an electron from Li metal.
  - B. By increasing the energy of incident light, the photocurrent is increased.
  - C. To eject an electron from Li, the frequency of the incident light must be higher than  $7.012 \times 10^{11}$  Hz.
  - D. To eject an electron from Li, the wavelength of the incident light must be shorter than 427.6 nm.
  - E. Electrons ejected by photon with higher energy have longer de Broglie wavelength.
- 15 Which of the following descriptions about an atom or ion are correct?
- A. Size of 1s orbital:  $\text{He}^+ < \text{H}$
  - B. Orbital size:  $1s < 2s < 3s$
  - C. Orbital energy of  $\text{Li}^{2+}$ :  $3s < 3p < 3d$
  - D. Penetration ability of orbital:  $s > p > d$
  - E. The first ionization energy:  $\text{Be} < \text{B}$

Section C: (40%) ※ 注意：請於試卷上「非選擇題作答區」標明題號並依序作答。

- 1 Terminology, description, and illustration:
- (a) How many degrees of freedom in the motions of translation, rotation, and vibration in a  $\text{C}_{60}$  molecule? (4%)
  - (b) Explain the essence of the Uncertainty Principle proposed by Heisenberg. (2%)
  - (c) Derive the half-life ( $t_{1/2}$ ) for a first-order reaction in terms of its rate constant. (2%)
  - (d) Describe the rate constant defined by S. Arrhenius. (2%)
  - (e) Draw all the *d*-orbitals with clear indication of the sign of each lobe. (5%)

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題號： 21  
科目：普通化學(A)

題號： 21  
共 5 頁之第 5 頁

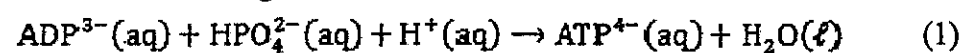
2 Mass spectrometry is a powerful analytical technique that is used to quantify the amount of molecules with different molecular masses.

(a) For the mass spectrum of a hypothetical molecule  $C_{120}$ , calculate the relative population of the following species observed in the spectrum, where we assume that the atomic mass of  $^{13}C$  is equal to 13 Da exactly. [Hint: The natural abundance of  $^{13}C$  and  $^{12}C$  is 1.1 % and 98.9 %, respectively] (5%)

Mass (Da)	1440	1441	1442	1443	1444	1445
Relative Population (%)		100			9	3

(b) Strictly speaking, the atomic mass of  $^{13}C$  is 13.003355 Da, not 13 Da exactly. Explain why. (5%)

3 The primary medium for free energy storage in living cells is adenosine triphosphate (ATP). Its formation from adenosine diphosphate (ADP) is driven by the metabolism of glucose:



We have  $\Delta G = +34.5 \text{ kJ/mol}$  and  $\Delta G = -2872.0 \text{ kJ/mol}$  for reactions (1) and (2), respectively.

(a) In the perspective of the Second Law, what is the maximum number of ATP molecules that can be formed per reaction of one glucose molecule? (5%)

(b) In reality, the reaction of one molecule of glucose leads to the formation of 38 molecules of ATP from ADP only. Explain why the number of ATP molecules generated from the glucose reaction is less than what we calculated in (a). (5%)

(c) With reference to (b), what fraction of the free energy released in the oxidation of glucose is stored in the ATP? (5%)

試題隨卷繳回