

※請將選擇題作答於試卷內之「選擇題作答區」。

Part A: Q1 -Q10 Single Choice (10 x 3 = 30 points)

(1) Which of the following 0.1 M aqueous solution has the lowest pH value?

- a. HClO
- b. NH_4Cl
- c. HClO_4
- d. H_3PO_4
- e. HF

(2) For the atomic orbital shown right, which of the description is correct?

- a. This is an orbital with a principal quantum number of 3
- b. There are two radial nodes
- c. It is a d_{z^2} orbital
- d. There is no electron density at the $x^2 - y^2 = 0$ plane
- e. None of the above.



(3) Which of the following atom has the largest first ionization energy?

- a. Li
- b. Cs
- c. C
- d. N
- e. O

(4) For potassium (K), which of the following atomic orbital has the highest energy?

- a. 1s
- b. 3s
- c. 3p
- d. 3d
- e. 4s

(5) Which of the following salt has the highest lattice energy?

- a. LiCl
- b. LiBr
- c. CaCl_2
- d. CaO
- e. MgO

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(6) For a 5.0 M H_3PO_4 solution, which of the following option is *incorrect*?
($K_{a1} = 7.5 \times 10^{-3}$; $K_{a2} = 6.2 \times 10^{-8}$; $K_{a3} = 4.8 \times 10^{-13}$)

- $\text{pH} = 0.713$
- $[\text{H}_2\text{PO}_4^-] = 1.9 \times 10^{-1} \text{ M}$
- $[\text{HPO}_4^{2-}] = 6.2 \times 10^{-8} \text{ M}$
- $[\text{PO}_4^{3-}] = 1.6 \times 10^{-19} \text{ M}$
- None of the above.

(7) Two isotopes of gallium are naturally occurring with $^{69}_{31}\text{Ga}$ at 60.0% (68.93 amu) and $^{71}_{31}\text{Ga}$ at 40.0% (70.92 amu). Which of the following description is *incorrect*?

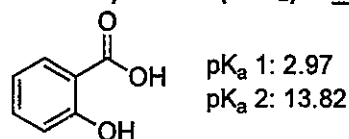
- $^{69}_{31}\text{Ga}$ and $^{71}_{31}\text{Ga}$ have the same number of electrons
- $^{71}_{31}\text{Ga}$ has more neutrons than $^{69}_{31}\text{Ga}$
- $^{71}_{31}\text{Ga}$ has higher first ionization energy than $^{69}_{31}\text{Ga}$
- $^{71}_{31}\text{Ga}$ has a slower diffusion rate than $^{69}_{31}\text{Ga}$
- The atomic mass of gallium is 69.73 amu

(8) Which description of water, methanol, and diethyl ether is correct?

molecule	Vapor pressure at 25°C (torr)
water	23.8
methanol	143
diethyl ether	536

- A water-methanol solution has a total vapor pressure higher than that of pure methanol.
- A methanol-diethyl ether solution has a total vapor pressure higher than that of pure methanol.
- The observed vapor pressure is proportional to the molecular weight
- If mixing water and methanol is exothermic, the observed total vapor pressure of the water-methanol solution will be higher than that calculated from Raoult's law.
- None of the above.

(9) Which of the following description of salicylic acid (SaH_2) is *incorrect*?



- All carbon atoms are sp^2 hybrid.
- The formal charge of all carbon is zero.
- The pH of a 0.1 M sodium salicylate (SaHNa) is 2.97
- At $\text{pH} = 2.97$, the concentration of salicylic acid equals to that of mono-deprotonated salicylic acid ($[\text{SaH}_2] = [\text{SaH}^-]$).
- None of the above.

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(10) There are four aqueous solutions with the following compositions. Please select the correct answer.

Solution A: 0.02 m KCl

Solution B: 0.01 m Na₂SO₄

Solution C: 0.02 m CH₃COOH

Solution D: 0.03 m glucose

- Solution D has the highest vapor pressure.
- Solution B has the largest freezing point depression.
- Solution A and C have the same boiling point.
- Solution D has the highest boiling point.
- None of the above

Part B: Q11-Q21 Multiple choices (11 x 5 = 55 points) ※請將選擇題作答於試卷內之「選擇題作答區」。
(There is *at least one correct* option)

(11) Which of the following descriptions of an atom are correct?

- ¹³₆C atom has 6 electrons and 6 protons.
- Electron configuration of an atom having 5 protons is [He]2s²2p¹.
- Electron configuration of Cu is [Ar]4s²3d⁹
- There are 6 half-filled orbitals in Cr.
- None of the above.

(12) Which of the following descriptions on Bohr Model are correct?

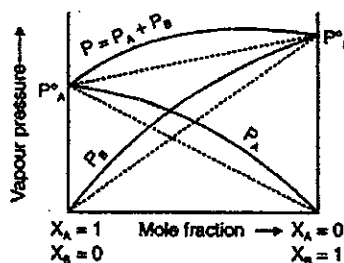
- Bohr model proposes that the electron in a hydrogen atom moves around the nucleus only in certain circular orbits.
- Bohr model states that the position and momentum of an electron in an atom cannot be determined precisely.
- Bohr Model can explain the observed atomic spectrum of He⁺ ion.
- In hydrogen atom, the ground state energy is 2.178 x 10⁻¹⁸ J
- In hydrogen atom, an electron falling from n = 2 to n = 1 emits a photon with a wavelength of 1.83 x 10⁻⁷ m.

(13) Consider a photoelectron experiment using Lithium metal (work function = 279.7 kJ/mol) as the cathode, which of the following statements are correct?

- It requires 279.7 kJ of energy to eject an electron from Li.
- A 400 nm light carries an energy of 1.7x10⁻¹⁹ J and can eject photoelectron from Li cathode.
- The electron ejected using 400 nm light has a kinetic energy lower than 19.5 kJ/mol.
- The electron ejected using 400 nm light has a de Broglie wavelength of 2.7 x 10⁻⁹ m.
- The first ionization energy of Li is 279.7 kJ/mol.

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- (14) Which of the descriptions of N_2 (28 g/mol) and CH_4 (16 g/mol) are correct?
- The average kinetic energy of a CH_4 molecule at 546 K is 6.81 kJ.
 - At 300 K, CH_4 has a lower average kinetic energy than N_2 .
 - At 273 K, the root mean square velocity of N_2 is 15.59 m/s.
 - At 300 K, CH_4 has a higher root mean square velocity than N_2 .
 - None of the above.
- (15) Which of the following statements are correct?
- The molecules SeS_2 , PCl_5 , and $TeCl_4$ all exhibit at least one bond angle, which is approximately 120° .
 - The formal charge of the S atom in SO_2 and SCl_2 is identical.
 - In NH_3 , the formal charge of the central N atom is -3.
 - A molecular orbital is formed by overlapping two half-filled atomic orbitals.
 - Both NNO and NON are linear molecules.
- (16) Two liquid volatile organic compounds were mixed with various mole fractions to form solutions. The relationship between vapor pressure and mole fraction is shown below. Please select the correct answer.



- The boiling point of liquid B is higher.
 - The dissolution (mixing) process of liquid A and B is exothermic.
 - The volume of the solution is smaller than the sum of volumes of liquid A and B.
 - The positive deviation from Raoult's law is because of the formation of a strong A-B attractive force in the solution.
 - None of the above.
- (17) H_2 gas generated from the reaction of Na (MW = 23 g/mol) and acetic acid was collected over water at 303 K and 1.00 atm.
- $$2 Na(s) + 2 CH_3COOH(aq) \rightarrow 2 CH_3COONa(aq) + H_2$$
- If the total pressure inside the gas collecting bottle is 1 atm, which of the following description is correct?
- The partial pressure of H_2 inside the bottle is 760 torr.
 - To generate 240 mL of gas, 0.43 g of Na must have reacted.
 - 40 mL of 0.5 M acetic acid is able to consume 0.43 g of Na.
 - The solution obtained from the reaction of 1.0 mole of Na and 1.0 mole of acetic acid has a pH value higher than 7. (pH > 7)
 - None of the above.

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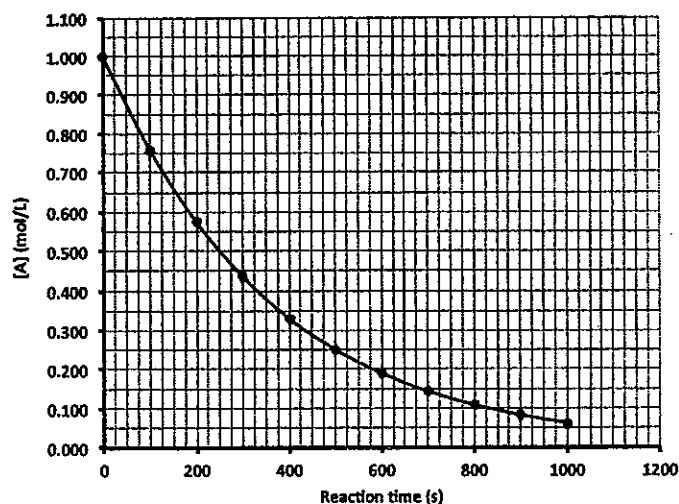
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- (18) In the upper atmosphere, ozone (O_3) undergoes two-step reaction at 298 K to yield O_2 .
First step: $O_3(g) + NO(g) \rightarrow NO_2(g) + O_2(g)$
Second step: $NO_2(g) + O(g) \rightarrow NO(g) + O_2(g)$

Which of the following descriptions are correct?

- The reaction is catalyzed by NO
 - NO is the intermediate
 - If the first step were the slower process, the reaction rate would be doubled when the concentration of $O_3(g)$ is doubled.
 - If the reaction rate is double at 308 K, the activation energy of the reaction is 11.9 kJ.
 - None of the above.
- (19) MgO (MW = 40.3 g/mol) has a density of 3.58 g/cm³ and has a crystal structure like NaCl.
Which of the following description is/are correct?
- There are four Mg²⁺ ions in a unit cell.
 - The $r_{Mg^{2+}}/r_{O^{2-}}$ is larger than 0.2247, but smaller than 0.414
 - The length of the edge of the unit cell (d) is 3.55 Å.
 - The estimated $r_{Mg^{2+}}$ is 0.615 Å.
 - The estimated $r_{O^{2-}}$ is 1.25 Å.

- (20) In an experiment, the concentration of reaction A decreases as the reaction proceeds.
According to the time profile of [A], which of the following descriptions are correct?



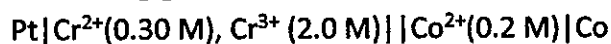
- A higher reaction temperature is expected to accelerate the reaction due to the lowering of reaction activation energy
- The rate constant is $2.77 \times 10^{-3} M^{-1}s^{-1}$.
- If the concentration of A is doubled, the reaction rate will be doubled.
- Addition of a catalyst will not affect the rate constant.
- None of the above.

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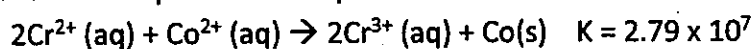
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(21) Considering the following galvanic cell at 25 °C:



Overall reaction equation and equilibrium constant

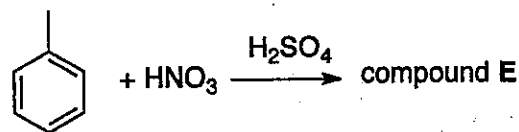
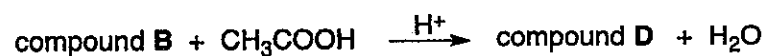
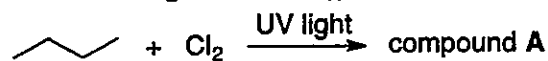


Which of the following statement is(are) correct?

- The cathode is Pt and the anode is Co
- The ΔG° of the reaction is -42.5 kJ/mol
- The cell potential (E) of the galvanic cell is 0.220 V
- The ΔG for the cell reaction at this condition is -29.1 kJ/mol
- None of the above

Part C: Organic reactions (15 points) ※ 注意：請於試卷上「非選擇題作答區」標明題號並依序作答。

(22) Product of the following reactions: ([ox] means oxidation)



Frequently used constants:

Speed of light in vacuum	$3 \times 10^8 \text{ m s}^{-1}$
Planck constant	$6.626 \times 10^{-34} \text{ J s}$
Boltzmann constant	$1.38 \times 10^{-23} \text{ J K}^{-1}$
Electron mass	$9.11 \times 10^{-31} \text{ kg}$
Proton mass	$1.67 \times 10^{-27} \text{ kg}$
Avogadro constant	$6.02 \times 10^{23} \text{ mol}^{-1}$
Universal gas constant	$0.082 \text{ L atm K}^{-1} \text{ mol}^{-1}$

試題隨卷繳回