

2019

Captains Tryout

Chemistry Lab

Orlando Science High School



Name: \_\_\_\_\_

Date: \_\_\_\_\_

Team: \_\_\_\_\_

**Direction:** This test consists of questions that are multiple choice, short answer, and long answer questions. All point values will be indicated next to the question. You have 50 minutes to complete the test. Good luck! 😊

Score:

/150

Rank:

---

\*Any questions pertaining to the test should be emailed to Jaehyun Ahn through [Ahn.Jaehyun@Outlook.Kr](mailto:Ahn.Jaehyun@Outlook.Kr)\*

## Physical Properties (75 points) :

Multiple Choice (2 point each)

1. Nishi was able to extract all the energy from the process of 16.2 grams of steam condensing from 100°C to 0°C. She wanted to use all the energies to melt  $x$  grams of ice. Determine the maximum value of  $x$ .
  - a) 43.4 kg
  - b) 36.6 kg
  - c) 130 kg
  - d) 6.77 kg
  - e) None of the above.
2. Chromium metal crystallizes as a body-centered cubic lattice. If the atomic radius of Cr is 1.25 angstroms, what is the density of Cr metal in  $\text{g/cm}^3$ ?
  - a) 5.52
  - b) 7.18
  - c) 14.4
  - d) 2.76
  - e) None of the above.
3. At a room temperature, KF is expected to be
  - a) Gas
  - b) Conducting solid
  - c) Liquid
  - d) Brittle Solid
  - e) Molten
4. What partial pressure of nitrogen gas is required in order for 0.00134 grams of the gas to dissolve in 13.1 mL of pure water? (The Henry's law constant for nitrogen gas is  $6.1 \times 10^{-4} \text{Matm}^{-1}$ )
  - a)  $6.2 \times 10^{-8} \text{atm}$
  - b)  $1.7 \times 10^{-1} \text{atm}$
  - c)  $6.0 \text{atm}$
  - d)  $2.9 \times 10^{-8} \text{atm}$
  - e) None of the above.
5. A solution of two liquids, A and B, shows negative deviation from Raoult's law. This means that:
  - a) The molecules of A interact strongly with other A-type molecules.
  - b) The two liquids have a positive heat of solution.
  - c) Molecules of A interact weakly, if at all, with B molecules.
  - d) The molecules of A hinder the strong interaction between B molecules.
  - e) None of the above.
6. Anthony is given a mixture of 10.40-g mixture of table sugar ( $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ ) and table salt ( $\text{NaCl}$ ). When this mixture is dissolved in 150. g of water, the freezing point is found to be -2.24 degrees Celsius. Calculate by percent mass of sugar in the original mixture.
  - a) 39.0%
  - b) 43.8%
  - c) 53.9%
  - d) 61.0%

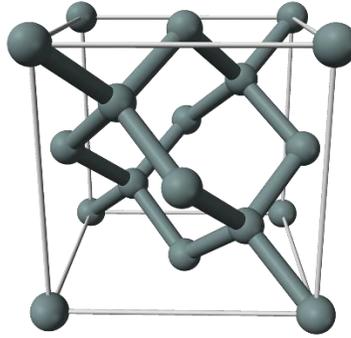
- e) None of the above.
7. How many of the following:  $F_2$ ,  $B_2$ ,  $O_2$ ,  $N_2$ , are paramagnetic?
- 0
  - 1
  - 2
  - 3
  - 4
8. Which of the following substances, when inserted into water, create a highly conducting solution?
- $NH_2NO_2$
  - $NH_4NO_3$
  - $H_2CO_3$
- I
  - II
  - I and III
  - II and III
  - All of the above
9. A precipitate forms when a solution that is 0.10 M in  $Cu^{2+}$ ,  $Pb^{2+}$ , and  $Ni^{2+}$  is saturated with  $H_2S$  and adjusted to pH=1. What sulfides are present in the precipitate?
- $[hydrosulfuric\ acid] = 0.10\ M; K_{a1} \times K_{a2} = 1.1 \times 10^{-24}$   
 $K_{sp} = CuS = 8.5 \times 10^{-45}, PbS = 7.0 \times 10^{-29}, NiS = 3.0 \times 10^{-21}$
- CuS, PbS, and NiS
  - PbS and NiS
  - NiS
  - CuS and PbS
  - CuS
10. At 40 degrees Celsius, heptane has a vapor pressure of about 92.2 torr and octane has a vapor pressure of about 31.2 torr. Assuming ideal behavior, what is the vapor pressure of a solution that contains twice as many moles of heptane as octane?
- 61.5 torr
  - 51.5 torr
  - 71.9 torr
  - 82.3 torr
  - None of the above

**Short Answer Questions (25 points) :**

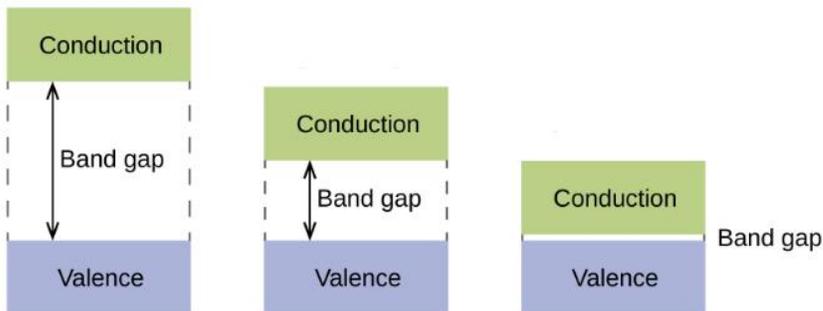
1. Wade was given the following list of vitamins: A, B, C, D, E, and K.
  - a) Determine which of the following are hydrophilic and hydrophobic. (3 points)
  - b) Using answer from a), determine which are water soluble. (2 point)
2. Nelson was given a solid that consists of a mixture of sodium nitrate and magnesium nitrate. When 6.50 g of this solid is dissolved in 50.0 g water, the freezing point is lowered by 5.40 degrees Celsius. What is the composition of the solid by mass? (5 points)
3. Arrange the following from lowest to highest ionization energy and give your explanation. (5 points)  
 $O_2$ ,  $O_2^-$ ,  $O_2^+$
4. When the excited electron in a hydrogen atom falls from  $n=5$  to  $n=2$ , a photon of blue light is emitted.
  - a) If an excited electron in  $He^+$  falls from  $n=4$ , to which energy level must it fall so that a similar blue light (as with hydrogen) is emitted? (3 points)
  - b) To what series did the electron of hydrogen atom fall to? (2 points)
5. NaCl is solid at room temperature. Why does it conduct electricity at aqueous solution but not at solid form? (5 points)

**Long Response Questions (30 Points)**

1.) Jaehyun is a chemist who is studying semiconductors and was given silicon.



- a) Observe the unit cell given above. How many atoms are in one unit cell of a silicon?
  
- b) Each length of the unit cell is 0.543 nm.
  - a. Determine its density in  $\text{g/cm}^3$
  
  - b. Determine the radius of the silicon atom in nm.
  
- c) Harshitha, an industrial engineer, states that there are other elements that can be used as semiconductor. State at least **one** other element that can act as a semiconductor.
  
- d) Jaehyun was given three molecular orbital energy levels. Determine which one describes silicon and explain.



- e) There are two different types of semiconductors. List the two and state how both types improve the conductivity of a substance.

- 2.) Gases and solids in the environment have different solubility level and affects our lives daily.
- a) Determine the solubility of nitrogen gas and oxygen gas in water. Justify your answer.
  
  - b) Gases such as carbon dioxide are slightly soluble in water although its non – polar.
    - I. State one reason why this is so.
  
    - II. State a reaction that supports the fact that carbon dioxide is slightly soluble in water.
  
  - c) Table salt, NaCl, is readily dissolve in water.
    - I. The dissolution of NaCl is an endothermic reaction, but it still dissolves spontaneously. Determine why this is so.
  
    - II. When a solid AgCl is being dissolved in water, table salt was added. Determine how this would affect the solubility of AgCl(s).
  
  - d) Solubility depends on temperature of the solution.
    - I. Determine if the solubility of solids, gases, or both increase or decreases with increasing temperature.
  
    - II. Justify your answer from part d.I)
  
  - e) Design a lab technique that can collect substances based on the criteria below.
    - I. Separation of ethanol and water.
  
    - II. Separation of collecting methane gas from a mixture of methane and ethanol gas.

## Acids and Bases (75 points):

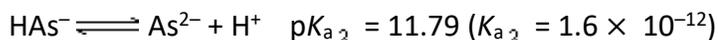
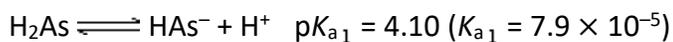
Multiple choice:

Each question is worth 2 points.

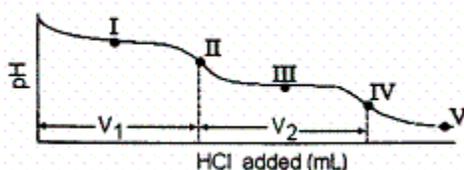
- Determine the equilibrium concentration of  $\text{H}_2\text{PO}_4^-$  in a 0.202 M solution of  $\text{H}_3\text{PO}_4(\text{aq})$ .  
 $K_{a1} = 7.5 \times 10^{-3}$ ,  $K_{a2} = 6.2 \times 10^{-8}$ ,  $K_{a3} = 4.8 \times 10^{-13}$ 
  - $1.1 \times 10^{-4} \text{M}$
  - $3.5 \times 10^{-2} \text{M}$
  - $3.9 \times 10^{-2} \text{M}$
  - $7.5 \times 10^{-3} \text{M}$
  - $6.2 \times 10^{-8} \text{M}$
- Carbonic acid is a diprotic acid with  $K_{a1} = 4.2 \times 10^{-7}$  and  $K_{a2} = 4.8 \times 10^{-11}$  at  $25^\circ\text{C}$ . The ion product for water is  $K_w = 1.0 \times 10^{-14}$  at  $25^\circ\text{C}$ . What is the hydroxide ion concentration of a solution that is 0.18M in sodium carbonate?
  - $6.1 \times 10^{-3} \text{M}$
  - $2.1 \times 10^{-4} \text{M}$
  - $6.5 \times 10^{-5} \text{M}$
  - $2.9 \times 10^{-6} \text{M}$
  - $2.7 \times 10^{-4} \text{M}$
- Calculate the pH of a 0.04 M solution of ascorbic acid ( $K_{a1} = 7.9 \times 10^{-5}$ ;  $K_{a2} = 1.6 \times 10^{-12}$ )
  - 11.2
  - 2.8
  - 5.5
  - 8.5
  - 11.8
- Which of the following species will not produce a basic solution when dissolved in dihydrogen monoxide?
  - Sulfur dioxide
  - Ammonia
  - Barium Oxide
  - Barium Hydroxide
  - None of the above
- Which of the following species cannot act as a Lewis base?
  - Aluminum ion
  - Oxygen ion
  - Hydroxide ion
  - Water
  - Hydrogen peroxide
- Jonathan was given solutions of 0.200 M of  $\text{HNO}_2$  and 0.200M  $\text{KNO}_2$  ( $K_a$  of  $\text{HNO}_2 = 4.00 \times 10^{-4}$ ). A buffer of 3.000 is needed. What volumes of  $\text{HNO}_2$  and  $\text{KNO}_2$  are required to make 1 liter of buffered solution?
  - 500 mL of each
  - 286 mL  $\text{HNO}_2$  and 714 mL  $\text{KNO}_2$
  - 413 mL  $\text{HNO}_2$  and 587 mL  $\text{KNO}_2$
  - 714 mL  $\text{HNO}_2$  and 286 mL  $\text{KNO}_2$

- e) None of the above
7. Consider the titration of 500.0 mL of 0.200 M NaOH with 0.800 M hydrochloric acid. How many milliliters of 0.800 M hydrochloric acid must be added to reach a pH of 13.000?
- 55.6 mL
  - 24.6 mL
  - 18.5 mL
  - 12.9 mL
  - None of the above

Consider the following information about ascorbic acid for questions 8 – 10.



The titration curve for disodium ascorbate,  $\text{Na}_2\text{As}$ , with standard HCl is shown below:



8. What major species is (are) present at point III?
- $\text{As}^{2-}$  and  $\text{HAs}^-$
  - $\text{HAs}^-$  only
  - $\text{HAs}^-$  and  $\text{H}_2\text{As}$
  - $\text{H}_2\text{As}$  only
  - $\text{H}_2\text{As}$  and  $\text{H}^+$
9. What is the pH at point III?
- 4.10
  - 7.95
  - 11.79
  - 12.39
  - None of the above
10. Which of the following is a major species at point IV?
- $\text{H}_2\text{As}$
  - $\text{HAs}^-$
  - $\text{As}^{2-}$
  - $\text{H}^+$
  - none of these

### Short Answer Questions (25 points)

1. When ranking acids from strongest to weakest, there are multiple ways to accomplish this. State at least two ways that this can be done and why these methods are effective.
2. There are three different definitions of acids and bases. State the definitions and its names.
3. A buffer was created by using 45.0 mL of 0.750 M acetic acid ( $K_a = 1.3 \times 10^{-5}$ ) and 55.0 mL of 0.700 M of  $\text{NaC}_2\text{H}_3\text{O}_2$ . What volume of NaOH must be added to change the pH of the original buffer solution by 2.5%
4. A student accidentally touched a substance that he couldn't identify. The substance gave a slippery texture. Is the substance an acid or a base? Explain in terms of chemistry.
5. Challenge! → What characteristics determine if a substance is either a superacid or a superbase?



2. A few drops of each of the indicators shown in the table below were placed in separate portions of a 1.0 M solution of a weak acid, HX. The results are presented in the last column of the table.

Indicator	Color of HIn	Color of In <sup>-</sup>	pKa of HIn	Color of 1.0 M HX
Bromophenol Blue	Yellow	Blue	4.0	Blue
Bromocresol Purple	Yellow	Purple	6.0	Yellow
Bromocresol Green	Yellow	Blue	4.8	Green
Alizarin	Yellow	Red	6.5	Yellow

- What makes an acid a “strong” or “weak”? Justify your answer with examples.
- HF is a weak acid, while HCl is a strong acid. Explain what causes such difference.
- How does an indicator work? What is the purpose of using an indicator?
- Using the information above, what is the approximate pOH of the solution containing HX?
- Calculate the approximate value of  $K_a$  for HX.