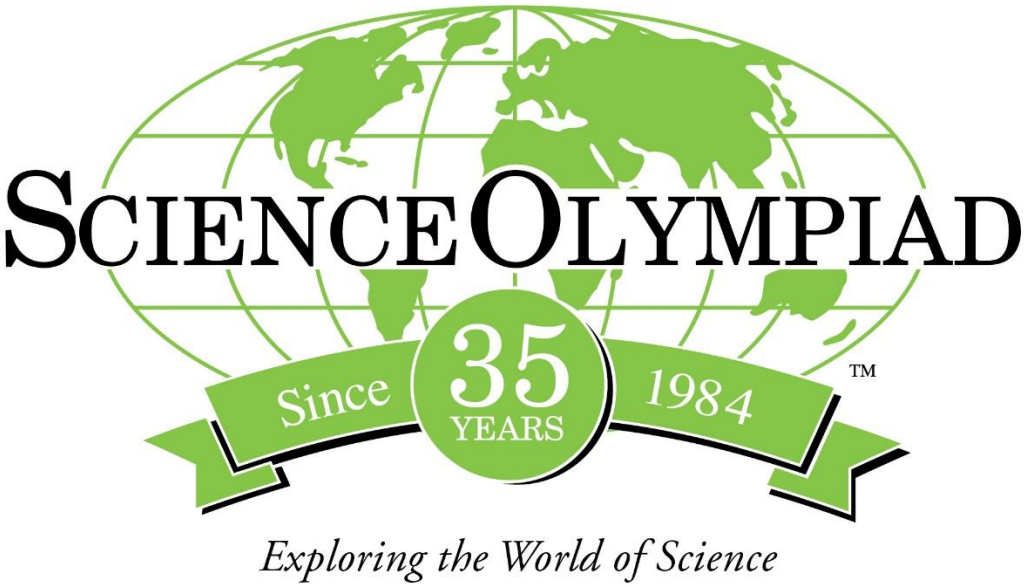
2019

Captains Tryout

Chemistry Lab

KEY

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

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℃ to 0℃. 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 angstograms, what is the density of Cr metal in 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 $6.1 \times 10^{-4} Matm^{-1}$)
   a) $6.2 \times 10^{-8} atm$
   b) $1.7 \times 10^{-1} atm$
   c) $6.0\ atm$
   d) $2.9 \times 10^{-8} atm$
   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 ($C_{12}H_{22}O_{11}$) and table salt (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?
a) 0
b) 1
c) 2
d) 3
e) 4

8. Which of the following substances, when inserted into water, create a highly conducting solution?
I. NH_2NO_2
II. NH_4NO_3
III. H_2CO_3
a) I
b) II
c) I and III
d) II and III
e) 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?

$$[hydrosulfuric\ acid] = 0.10\ M; Ka1 \times Ka2 = 1.1 \times 10^{-24}$$
$$Ksp = CuS = 8.5 \times 10^{-45}, PbS = 7.0 \times 10^{-29}, NiS = 3.0 \times 10^{-21}$$

a) CuS, PbS, and NiS
b) PbS and NiS
c) NiS
d) CuS and PbS
e) 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?
a) 61.5 torr
b) 51.5 torr
c) 71.9 torr
d) 82.3 torr
e) 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)

   A,D,E,K→Hydrophobic
   B and C → Hydrophilic

   b) Using answer from a), determine which are water soluble. (2 point)

   B and C

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)

   36.3% of Magnesium Nitrate
   63.7% Sodium Nitrate

3. Arrange the following rom lowest to highest ionization energy and give your explanation. (5 points)
   O_2, O_2^-, O_2^+

   O_2^-, O_2, O_2^+
   Bond Order increases from left to right → Causing increase in ionization energy.

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)

   n=3

   b) To what series did the electron of hydrogen atom fall to? (2 points)

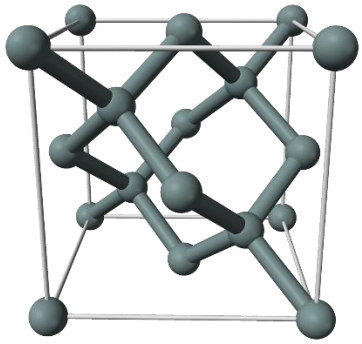
   Paschen Series

5. NaCl is solid at room temperature. Why does it conduct electricity at aqueous solution but not at solid form? (5 points)

   A solid ionic compound does not **conduct electricity** because the **ions** are not free to move.
   At **aqueous form** , the ions are free to move.

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?

8 atoms

b) Each length of the unit cell is 0.543 nm.

a. Determine its density in g/cm^3

$2.33\ g/cm^3$

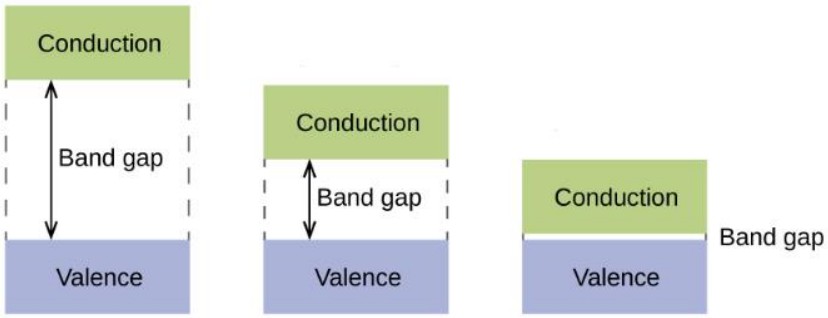
b. Determine the radius of the silicon atom in nm.

0.272 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.

Germanium

d) Jaehyun was given three molecular orbital energy levels. Determine which one describes silicon and explain.



The second energy level describes silicon. Silicon is a semiconductor, which the second energy band describes.

(The first → insulator. The third →Metal)

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

p-type → Provides extra "free" electron which enhances conductivity.

n-type→ Creates vacancy in the valence band. These "empty holes" are good charge carriers, enhancing the conductivity

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.

Not soluble. Nitrogen and oxygen gases are non-polar, which makes them insoluble in water.

b) Gases such as carbon dioxide are slightly soluble in water although its non – polar.

I. State one reason why this is so.

Carbon dioxide reacts with water to create carbonic acid. (Also its bonds are polar)

II. State a reaction that supports the fact that carbon dioxide is slightly soluble in water.

$CO_2+H_2O \rightarrow H_2CO_3$

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.

The nature wants increase in entropy. Although dissolution of NaCl requires energy, the increase in disorder allows this process to be spontaneous. (Refer to Gibbs Free energy)

II. When a solid AgCl is being dissolved in water, table salt was added. Determine how this would affect the solubility of AgCl(s).

Decrease the solubility through the common ion effect.

d) Solubility depends on temperature of the solution.

I. Determine if the solubility of solids, gases, or both increase or decreases with increasing temperature.

Gases → Decrease

Solid → Usually increases

II. Justify your answer from part d.I)

Gases interaction with solutions is an exothermic reaction. By Le Chatelier's principle, solubility decrease.
Solids interaction with solutions is an endothermic reaction. By Le Chatelier's principle, solubility increase.

e) Design a lab technique that can collect substances based on the criteria below.

I. Separation of ethanol and water.

Distillation

II. Separation of collecting methane gas from a mixture of methane and ethanol gas.

Insert the mixture into water. Ethanol gas dissolves in water while methane gas will not and form bubble. Then it will be released into the top of the container as it is less dense than air.

Acids and Bases (75 points):

Multiple choice:

Each question is worth 2 points.

1. Determine the equilibrium concentration of $H_2PO_4^-$ in a 0.202 M solution of H_3PO_4(aq).
$$Ka1 = 7.5 \times 10^{-3}, Ka2 = 6.2 \times 10^{-8}, Ka3 = 4.8 \times 10^{-13}$$
   a) $1.1 \times 10^{-4} M$
   b) $3.5 \times 10^{-2} M$
   c) $3.9 \times 10^{-2} M$
   d) $7.5 \times 10^{-3} M$
   e) $6.2 \times 10^{-8} M$
2. Carbonic acid is a diprotic acid with $Ka1 = 4.2 \times 10^{-7}$ and $Ka2 = 4.8 \times 10^{-11}$ at 25°C. The ion product for water is $Kw = 1.0 \times 10^{-14}$ at 25°C. What is th hydroxide ion concentration of a solution that is 0.18M in sodium carbonate?
   a) $6.1 \times 10^{-3} M$
   b) $2.1 \times 10^{-4} M$
   c) $6.5 \times 10^{-5} M$
   d) $2.9 \times 10^{-6} M$
   e) $2.7 \times 10^{-4} M$
3. Calculate the pH of a 0.04 M solution of ascorbic acid ($Ka1 = 7.9 \times 10^{-5}; Ka2 = 1.6 \times 10^{-12}$)
   a) 11.2
   b) 2.8
   c) 5.5
   d) 8.5
   e) 11.8
4. Which of the following species will not produce a basic solution when dissolved in dihydrogen monoxide?
   a) Sulfur dioxide
   b) Ammonia
   c) Barium Oxide
   d) Barium Hydroxide
   e) None of the above
5. Which of the following species cannot act as a lewis base?
   a) Aluminum ion
   b) Oxygen ion
   c) Hydroxide ion
   d) Water
   e) Hydrogen peroxide
6. Jonathan was given solutions of 0.200 M of HNO_2 and 0.200M KNO_2 (Ka of $HNO_2 = 4.00 \times 10^{-4}$). A buffer of 3.000 is needed. What volumes of HNO_2 and KNO_2 are required to make 1 liter of buffered solution?
   a) 500 mL of each
   b) 286 mL HNO_2 and 714 mL KNO_2
   c) 413 mL HNO_2 and 587 mL KNO_2
   d) 714 mL HNO_2 and 286 mL 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?

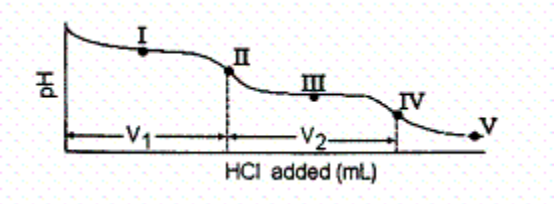
a) 55.6 mL
b) 24.6 mL
c) 18.5 mL
d) 12.9 mL
e) None of the above

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

$H_2As \rightleftharpoons HAs^- + H^+$ $pK_{a_1} = 4.10$ ($K_{a_1} = 7.9 \times 10^{-5}$)

$HAs^- \rightleftharpoons As^{2-} + H^+$ $pK_{a_2} = 11.79$ ($K_{a_2} = 1.6 \times 10^{-12}$)

The titration curve for disodium ascorbate, Na_2As, with standard HCl is shown below:



8. What major species is (are) present at point III?

a) As^{2-} and HAs^-
b) HAs^- only
c) HAs^- and H_2As
d) H_2As only
e) H_2As and H^+

9. What is the pH at point III?

a) 4.10
b) 7.95
c) 11.79
d) 12.39
e) None of the above

10. Which of the following is a major species at point IV?

a) H_2As
b) HAs^-
c) As^{2-}
d) H^+
e) 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.

   Comparing ka values.

   ARIO

   - Atoms (Which one bear the charge)
   - Resonance (Stability)
   - Induction (Inductive effects that stabilize one of the conjugate base)
   - Orbital (Determine what orbital the negative charge can be found)

2. There are three different definitions of acids and bases. State the definitions and its names.
   1. Lewis Acids and Base: (Acid)→ Accepts electrons. (Base) → Donates electrons
   2. Arrhenius Acids and Base: (Acid) → Produces hydrogen ion. (Base) → Produces Hydroxide ion.
   3. Bronsted Lowry Acids and Base: (Acid) → Donates proton. (Base) → Accepts proton.

3. A buffer was created by using 45.0 mL of 0.750 M acetic acid ($Ka = 1.3 \times 10^{-5}$) and 55.0 mL of 0.700 M of $NaC_3H_5O_2$. What volume of NaOH must be added to change the pH of the original buffer solution by 2.5%

   49 mL

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.

   The substance is a base. Base dissolve fatty acids and oils from your skin. This reduces frictions between your fingers causing it to be slippery.

5. Challenge! → What characteristics determine if a substance is either a superacid or a superbase?

   Super Acids→ Acidity great than that of 100% pure sulfuric acid.

   Super Bases→ Extremely basic compounds/substances that has a high affinity for protons.

Long Response Questions:

1. Jacob and Jonathan, the two famous chemists wanted to observe the following acids and base reaction.

   Hydrogen Cyanide + Sodium Hydroxide ⇋ Cyanide Ion + Water

   Ka=6.2×10^{-10}

   To titrate the sample of hydrogen cyanide, the chemists brought 50.0 mL sample of 0.100 M of Hydrogen Cyanide and 0.100 M of Sodium Hydroxide.

   a. Complete the net ionic equation and state the chemical formula for each substance.

   $$HCN + OH^- \leftrightarrow CN^- + H2O$$

   b. Calculate the pH after 8.00 mL of 0.100 M Sodium Hydroxide was added.

   8.49

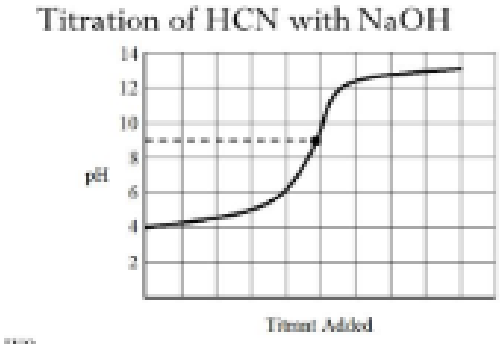
   c. If Jonathan were to insert a litmus paper into the solution (after all the sodium hydroxide was added) , what color should he expect to see? Justify your answer.

   Blue. The solution is basic.

   d. Jacob was curious what would happen if instead of sample of hydrogen cyanide, a sample of acetic acid were inserted. Describe what would occur and why.

   The solution would be more acidic as acetic acid has a higher ka value that HCN

   e. Draw a titration curve graph for the following scenario presented in the question.



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^-	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

a. What makes an acid a "strong" or "weak"? Justify your answer with examples.

A substance with a very high ka values or completely dissociates and donates the hydrogen ion.

Ex: HCl, HBr, HI

b. HF is a weak acid, while HCl is a strong acid. Explain what causes such difference.

HF has a very strong covalent bond due to fluroine's high affinity for hydrogen. → Doesn't lose hydrogen easily unlike HCl whose bonding is weaker compare to HF.

c. How does an indicator work? What is the purpose of using an indicator?

pH indicators detect the presence of H+ and OH- . They do this by reacting with H+ and OH- : they are themselves weak acids and bases. If an indicator is a weak acid and is color and its conjugate base has a different color, deprotonation causes a color change. It is used to mark the end point of a titration.

d. Using the information above, what is the approximate pOH of the solution containing HX?

pOH=9

e. Calculate the approximate value of Ka for HX.

$Ka=1 \times 10^{-10}$