

Name: _____

Score: _____/275 pts.

2019 SSSS: Acton-Boxborough Regional High School – Chemistry Lab TestWritten by Christopher Wang (19wangc@abschools.org)**50 MINUTES, FIVE DOUBLE-SIDED PAGES OF NOTES**

Physical Properties (138 points):**Fill in the Blank (1 point each, 10 points total)**

- 1) A material that, when stressed, does not deform before it breaks, is said to be _____.
- 2) The type of magnetism that a refrigerator magnet exhibits is called _____.
- 3) The property of two substances, often liquids, to dissolve in each other and form a homogenous mixture in all proportions is called _____.
- 4) When the solid and liquid forms of a substance exist together, and the vapor pressure of the liquid is greater than that of the solid, then the phase change that will occur is _____.
- 5) _____ (either name or formula) is one example of a ternary acid.
- 6) The density of water reaches a maximum at _____ °C.
- 7) The physical property of _____ is often characterized by the ability of the substance to be stretched into a wire.
- 8) The solubility of a gas _____ (increases / decreases) with increasing pressure and _____ (increases / decreases) with increasing temperature.
- 9) 1.00 g of helium gas consists of _____ He atoms.
- 10) Aqueous potassium permanganate gives the solution a _____ color.

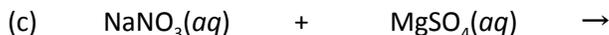
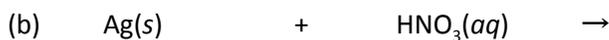
Open Response and Calculations (128 points)

1) Match each of the following descriptions to one of the four types of crystalline solids. (6 points)

(a) ionic (b) metallic (c) covalent network (d) covalent molecular

- Brittle, non-conductive solid at STP, but highly conductive when heated to temperatures above 801 °C. _____
- Very high hardness and thermal conductivity. Will only sublime, not melt, when exposed to high temperatures at atmospheric pressure. _____
- Melting point of 30 °C at standard pressure. As a liquid, very viscous and nonvolatile. Non-directional bonding. _____
- Conducts electricity as both a solid and a liquid. Malleable and ductile. _____
- White, crystal solid with a melting point of 78.2 °C. However, is extremely volatile and sublimates easily at room temperature. Directional bonding. _____
- Little to no electronegativity difference between atoms. Sublimation point is 3642 °C at standard pressure; will only melt at pressures of 100 atm or higher. _____

2) Predict the products of the following chemical reactions, or write NR if no reaction occurs. Balance all equations where necessary. (6 points)



3) You are investigating the properties of a concentrated solution over a wide range of varying temperatures. Should you use molarity or molality as a measurement for the solution concentration? Explain. (4 points)

4) When calcium sulfate dihydrate (also known as gypsum) is heated at temperatures of 100 °C to 150 °C, it decomposes into calcium sulfate hemihydrate (also known as plaster of Paris). The hemihydrate does not appreciably decompose into the anhydrous form until temperatures as high as 170 °C to 180 °C.

- 30.0 g of gypsum are heated at 140 °C to be decomposed into plaster of Paris. After heating for 15 minutes, the remaining mass of the solid is 28.3 g. Calculate the percent yield of water for this reaction. (6 points)

- What is one reason that could account for the fact that the percent yield is not 100%? (2 points)

5) A 0.488-*m* solution of a salt containing chromium and nitrate ions has a boiling point of 101.00 °C. What is the oxidation number of chromium in this salt? (5 points)

6) Solid potassium hydroxide is gradually dissolved in 460 mL of 0.15-*M* calcium perchlorate. Will potassium perchlorate ($K_{sp} = 1.2 \times 10^{-4}$) or calcium hydroxide ($K_{sp} = 1.3 \times 10^{-6}$) precipitate first? What mass of potassium hydroxide must be added so that this precipitate begins to form? Assume that the potassium hydroxide has a negligible effect on the volume of the solution. (8 points)

7) The international prototype kilogram, abbreviated the IPK, is a cylinder manufactured from a platinum-iridium alloy with a mass of exactly one kilogram. Both the height and the diameter of the cylinder measure 38.94 mm. If the density of platinum is 21.45 g/cm^3 and the density of iridium is 22.56 g/cm^3 , calculate the mass percentage of each metal in the alloy. (8 points)

8) Order the following sets of compounds from lowest to highest melting/boiling point. (12 points)

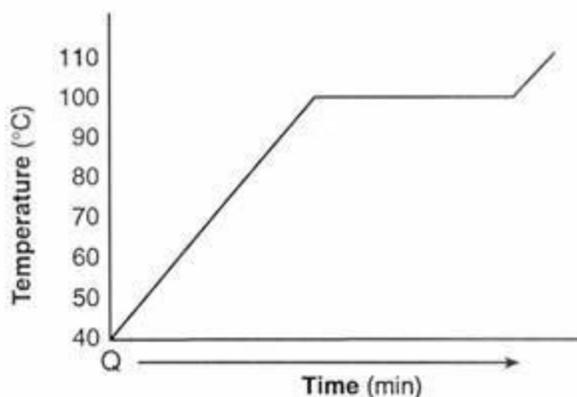
• H_2O CH_3OH $\text{CH}_3\text{CH}_2\text{OH}$ C_3H_8 (boiling point)

• CH_4 CH_3F CH_3Cl CH_3Br (melting point)

• CaCl_2 NaCl CaO Na_2O (melting point)

• CH_3OH $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ CH_3OCH_3 $\text{HO}-\text{CH}_2\text{CH}_2-\text{OH}$ (boiling point)

9) The graph depicts the temperature of a sample of water when heat is supplied at a constant rate:



From 40 °C to 100 °C, draw a line that represents the change in temperature of a sample of liquid carbon tetrabromide of equal mass when heat is added at the same rate. Explain why, on a molecular level, the line for carbon tetrabromide is different than the line for water at these temperatures. You can assume that carbon tetrabromide does not undergo any phase changes in this temperature range. (7 points)

10) Erythrose is an organic molecule with the appearance of a light yellow syrup when isolated, first extracted from rhubarb plants in 1849. It contains the elements carbon, hydrogen, and oxygen.

- Complete combustion of erythrose with 3.00 g of oxygen gas yields 4.13 g of carbon dioxide and 1.69 g of water vapor. What is the empirical formula of erythrose? (4 points)
- Erythrose is a non-ionizing, nonvolatile solute when dissolved in water. 15.0 g of erythrose is dissolved in 90.0 g of water, and the new freezing point of the solution is $-2.58\text{ }^{\circ}\text{C}$. What is the molecular formula of erythrose? (5 points)

11) For each row, circle the element that best fits the description: (6 points)

• Most conductive	Na	Ag	Si	Ne
• Least reactive	Li	Cu	Zn	Pb
• Largest atomic radius	K	Ca	Cr	Xe
• Greatest first ionization energy	Br	Zn	Kr	Hg
• Most malleable	Au	Rb	Ni	Sn
• Lowest melting point	Be	Ga	Fe	Ti

12) An element exhibits the following characteristics. Identify whether each is a physical or chemical property and give the identity of the element. (This is like a knockoff version of Chem Clue!) (5 points)

• Exists most stably as a pure element	<i>Physical</i>	<i>Chemical</i>
• Exists in the gaseous form at atmospheric pressure	<i>Physical</i>	<i>Chemical</i>
• Non-toxic to human cells	<i>Physical</i>	<i>Chemical</i>
• Approximately as soluble in water as oxygen gas	<i>Physical</i>	<i>Chemical</i>
• Low thermal conductivity	<i>Physical</i>	<i>Chemical</i>
• Decay product of radioactive potassium	<i>Physical</i>	<i>Chemical</i>

Identity of the element: _____

13) What is the identity of a diatomic gas with a density of 0.00169 g/mL at STP? Points will not be awarded for guessing without work shown. (6 points)

14) The K_{sp} value for barium hydroxide is 5.0×10^{-3} . What is the pH of a saturated solution? (6 points)

15) 7.75 L of water is necessary to dissolve 1.00 g of strontium fluoride. What volume of 0.025-M sodium fluoride is needed to dissolve 1.00 g of strontium fluoride? Assume negligible change to the volume of the solution upon dissolving. (8 points)

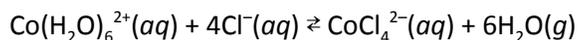
16) An aqueous solution containing 75.0 g of water has a freezing point of -25.6°C . How much water must be added so that the solution boils at 102.40°C ? (6 points)

17) A solution contains an unknown dissolved metal cation to be identified. Qualitative analysis produces the following observations in separate samples of the solution:

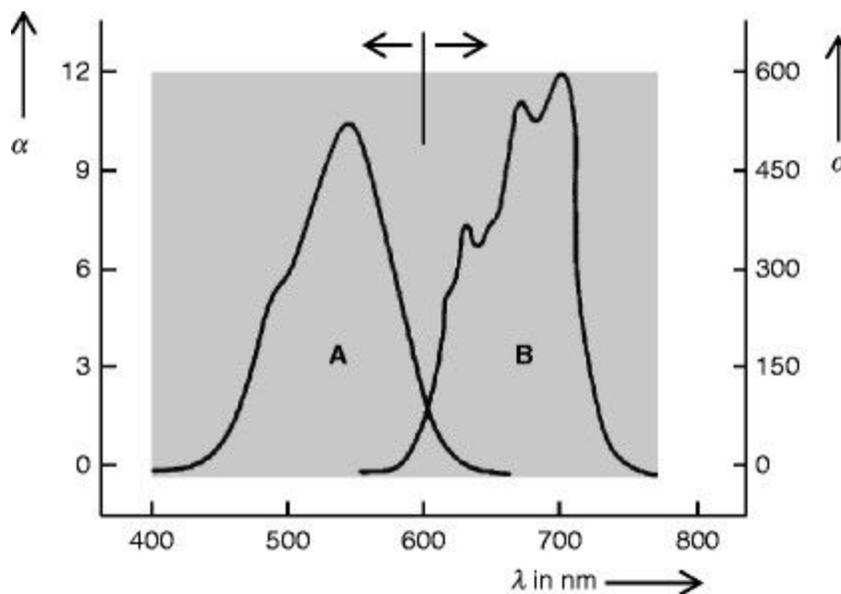
- Addition of HCl produces no observable reaction
- Addition of NaOH produces a blue precipitate
- Addition of H_2S in acidic solution produces a black precipitate that burns blue-green
- Addition of Na_2CO_3 produces a green precipitate
- Addition of solid iron causes the cation to precipitate as metal
- Addition of solid silver produces no observable reaction

Identify the cation dissolved in the solution. (4 points)

18) The following equation shows the equilibrium between two complex cobalt ions:

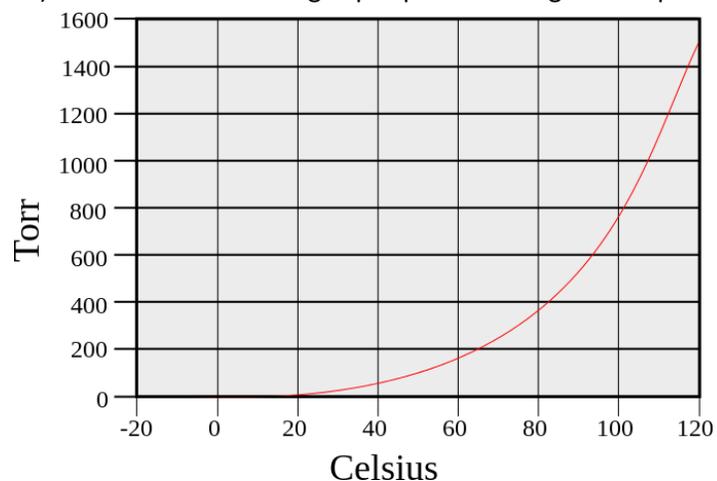


The $\text{Co}(\text{H}_2\text{O})_6^{2+}(\text{aq})$ is pink, while the $\text{CoCl}_4^{2-}(\text{aq})$ is blue. The following graph depicts two different possible absorption spectra that vary with the equilibrium in the solution:



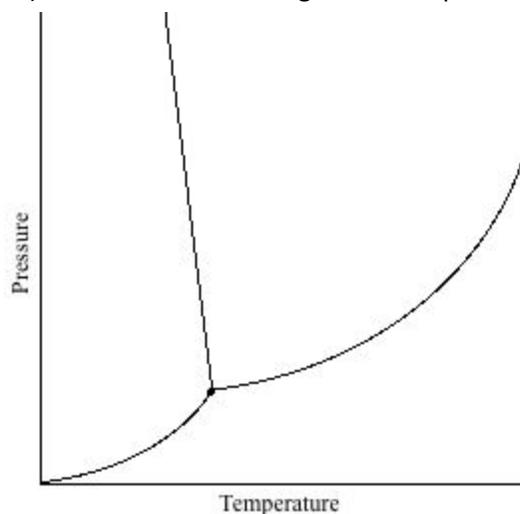
- The absorption spectrum labeled A shows the absorption of the solution when cooled to its freezing point, while the absorption spectrum labeled B shows its absorption when heated to its boiling point. Is the forward reaction endothermic or exothermic? Explain. (6 points)
- If the absorption spectrum of a beaker containing these ions was intermediate between A and B, which spectrum, A or B, would it resemble more if... (4 points)
 - CoCl_4^{2-} was added? **A** **B**
 - hydrochloric acid was added? **A** **B**
 - silver nitrate was added? **A** **B**
 - the solution was diluted? **A** **B**

19) Consider the following vapor pressure diagram for pure water:



On the graph, draw the curve that represents the vapor pressure of an aqueous solution. (2 points)

20) Consider the following unlabeled phase diagram of an unknown substance:



- Label the three states of matter in the diagram. (3 points)
- Draw new curves to show the change in the phase diagram when a substance is dissolved in this solvent. (3 points)
- Given that you know it is either one or the other, does this phase diagram represent the properties of water or benzene (C_6H_6)? What feature allows you to tell, and why is this feature different between the two different solvents? (6 points)

Acids and Bases (237 points):**Multiple Choice (1 point each, 15 points total)**

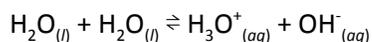
____ 1) An unknown solution is poorly conductive and forms bubbles when nickel is added. The solute is most likely:

- a. a strong base
- b. a weak base
- c. a strong acid
- d. a weak acid

____ 2) Which of the following is always true?

- a. the conjugate of a strong acid is a strong base
- b. the conjugate of a strong acid is a weak base
- c. the conjugate of a weak acid is a strong base
- d. the conjugate of a weak acid is a weak base

____ 3) Consider the following equation:



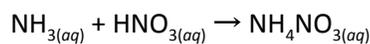
This reaction is an example of all of the following EXCEPT:

- a. hydrolysis
- b. deprotonation
- c. autoionization
- d. amphoterism

____ 4) Which of the following acids has the highest K_a value?

- a. HF
- b. HCl
- c. HBr
- d. HI

____ 5) Consider the following reaction:



Is this considered a neutralization reaction?

- a. yes, the product is neutral in solution
- b. yes, NH_3 accepts a proton from HNO_3
- c. no, water is not a product
- d. no, NH_3 is not an Arrhenius base

____ 6) A base is gradually added to a buffer solution. The buffer capacity is exceeded when:

- a. all the buffering acid has reacted
- b. all the buffering base has reacted
- c. the concentrations of hydronium and hydroxide are equal
- d. the K_b of the added base is higher than the K_b of the buffering base

____ 7) Which of the following compounds acts as a Brønsted-Lowry base but not as an Arrhenius base?

- a. H_2O
- b. BF_3
- c. NH_3
- d. LiOH

____ 8) Which of the following compounds is most likely to act as a Lewis base?

- a. NH_4^+
- b. BBr_3
- c. CO_2
- d. PCl_3

____ 9) Which of the following is/are true of a solution formed by dissolving BaO in water?

- I. red litmus paper will turn blue
- II. blue litmus paper will turn red
- III. $\text{pH} > \text{pOH}$

- a. I only
- b. II only
- c. I and III
- d. II and III

____ 10) Which description is true of a solution formed by dissolving SO_3 in water?

- a. strong conductor with a pH above 7
- b. strong conductor with a pH below 7
- c. weak conductor with a pH above 7
- d. weak conductor with a pH below 7

____ 11) What type of solution is formed by dissolving KNO_2 in water?

- a. neutral
- b. acidic
- c. basic
- d. not enough information

____ 12) What type of solution is formed by dissolving Sb_2O_3 in water?

- a. neutral
- b. acidic
- c. basic
- d. not enough information

____ 13) Will a solution of sodium formate (NaCHO_2) be an effective buffer?

- a. yes, it produces acidic Na^+ and basic CHO_2^-
- b. yes, it produces acidic HCHO_2 and basic CHO_2^-
- c. no, there is not enough acid
- d. no, there is not enough base

____ 14) The pH of 12 M hydrochloric acid is:

- a. -1.38
- b. -1.08
- c. -0.78
- d. 0

____ 15) 1.60 mL of 0.100 M sodium hydroxide is used to titrate 2.50 mL of oxalic acid. What is the concentration of the oxalic acid solution?

- a. 0.032 M
- b. 0.064 M
- c. 0.078 M
- d. 0.13 M

Open Response and Calculations (122 points total)

1) A scientist is deciding whether to add K_3PO_4 , K_2HPO_4 , or KH_2PO_4 to an aqueous solution of H_3PO_4 .

a) Which salt will have the greatest effect on the pH of the solution? (1 point)

b) Which salt will have the least effect on the pH of the solution? (1 point)

c) Does the pH of the solution increase or decrease when one of these salts is added? (1 point)

d) Do the K_a values of H_3PO_4 increase, decrease, or stay the same if K_2HPO_4 is added? (1 point)

e) Does the concentration of PO_4^{3-} increase, decrease, or stay the same if KH_2PO_4 is added? (1 point)

f) Identify all amphoteric species in the H_3PO_4 solution if K_3PO_4 is added. (3 points)

2) $K_{a1} = 4.3 \times 10^{-7}$ and $K_{a2} = 5.6 \times 10^{-11}$ for carbonic acid, and $K_b = 1.8 \times 10^{-5}$ for ammonia. What change, if any, will occur if phenolphthalein is added to a solution of ammonium bicarbonate? Explain. (5 points)

3) 0.92 g of an unidentified Group 1A metal oxide is dissolved in enough water to produce 650 mL of solution with a pH of 12.18. What is the identity of the metal? (8 points)

4) a) Which of the following has a higher K_a : HSO_3^- or HTeO_3^- ? Explain. (4 points)

b) Which of the following has a higher K_b : H_2AsO_3^- or H_2AsO_4^- ? Explain. (4 points)

c) Does HS^- have a higher tendency to act as an acid or as a base? Explain. (4 points)

5) Pyruvic acid is a monoprotic organic acid produced by cells during glycolysis. The conjugate base, pyruvate, is 41.39% carbon, 3.47% hydrogen, and 55.14% oxygen by mass and has a K_b of 3.16×10^{-12} . When 9.34 g of pyruvic acid is dissolved in enough water to produce 265 mL of solution, the pH is 1.468. For pyruvic acid, calculate K_a and determine the molecular formula. (14 points)

6) A scientist wants to create 2.5 L of a buffer solution containing ammonia ($K_b = 1.8 \times 10^{-5}$) and ammonium chloride with an initial pH of 9.00 that does not change by more than 0.30 when 15 g of lithium hydroxide is added. What minimum initial concentration of each component does he need? Assume that the volume remains constant when the lithium hydroxide is added. (14 points)

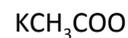
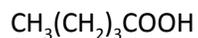
7) The pH of pure water at 85 °C is 6.26. However, neither red nor blue litmus paper changes color when placed in pure water at 85 °C.

a) Is pure water acidic, basic, or neutral at 85 °C? Explain. (3 points)

b) What is the pOH of pure water at 85 °C? (1 point)

c) Is the dissociation of water into ions endothermic or exothermic? Explain. (4 points)

8) a) A scientist wishes to identify the unknown solute in a weakly acidic solution. Which compounds might be the identity of the mystery solute? Circle ALL possible answers. (6 points)



b) The scientist decides to investigate further and discovers that the solution is strongly conductive. Which compound from the table is most likely to be the identity of the solute? Explain. (3 points)

9) An aqueous solution of hydrocyanic acid with an unknown concentration has a starting pH of 4.82. 7.50 mL of the solution is titrated to the equivalence point with 13.70 mL of 0.100 M barium hydroxide. Calculate K_a for hydrocyanic acid and find the pH of the titrated solution at the equivalence point. Assume that the final volume is equal to the volume of the two solutions added together. (14 points)

10) The indicator methyl orange ($K_a = 3.4 \times 10^{-4}$) is a weak acid that is red when undissociated and yellow when ionized. A color change from yellow is discernible when the concentration of undissociated methyl orange is at least a tenth of the concentration of the conjugate base. Selenic acid (H_2SeO_4) is a strong acid with $K_{a2} = 2.2 \times 10^{-2}$. What initial concentration of selenic acid is necessary for methyl orange to exhibit a visible change in color? Assume that the concentration of methyl orange is negligible. (15 points)

11) Citric acid is a triprotic organic acid ($K_{a1} = 8.4 \times 10^{-4}$, $K_{a2} = 1.8 \times 10^{-5}$, $K_{a3} = 4.0 \times 10^{-6}$) found in the juices of citrus fruits with a molar mass of 192 g/mol. A 55 mL sample of lemon juice has a pH of 2.29. How many fully deprotonated citrate ions are present after 0.11 g of sodium dihydrogen citrate is added? Assume that the volume is constant and that all H^+ ions are produced by the first dissociation. (15 points)

