Total: _____/140
Rank: _____

Names: _____

_____

Team Name: _____

Team Number: _____

Division C: Chemistry Lab

KEY

DO NOT OPEN UNTIL INSTRUCTED

Please Provide Team Number on All Pages Submitted with the Test

Station 1 – Written : 25 minutes
Station 2 – Lab A/B : 10 minutes
Station 3 – Lab B/A : 10 minutes
You will be provided with a periodic table. You can go back to the written test at any time.

You may separate the sheets, but be certain to write your team number on each if you do so.

----------DO NOT WRITE BELOW THIS LINE ----------

Supervisor/Assistant Check off Each Item

Lab Coat / Apron to Knees _____
Pants or Skirts to Ankles _____
Long Sleeved Shirt and
Apron or Coat _____
Closed Toe Shoes _____
Indirect Vent Goggles _____
Satisfactory Clean-up _____

Unsafe procedures noted at any station:
1._____
2._____
3._____
4._____

Team # _____

1. **PERIODICITY** (2 points) - Arrange these atoms and ions in order of decreasing size: Mg^{2+}, Ca^{2+}, and Ca.

   $Ca > Ca^{2+} > Mg^{2+}$.

2. **PERIODICITY** (2 points) - Which of the following atoms and ions is largest: S^{2-}, S, O^{2-}?

   S^{2-}

3. **PERIODICITY** (2 points) - Arrange the following atoms in order of increasing size: P, S, As, Se.

   S < P < Se < As

4. **PERIODICITY** (2 points) - Arrange the ions K+, Cl^-, Ca^{2+}, and S^{2-} in order of decreasing size.

   $S^{2-} > Cl^- > K^+ > Ca^{2+}$.

5. **PERIODICITY** (4 points) - Which of the following compounds are soluble? Check all that apply.

X	Magnesium sulfide
X	Ammonium sulfide
	Magnesium hydroxide
X	Lithium hydroxide
	Silver chloride
X	Sodium carbonate
	Barium carbonate
X	Silver nitrate
X	Barium nitrate

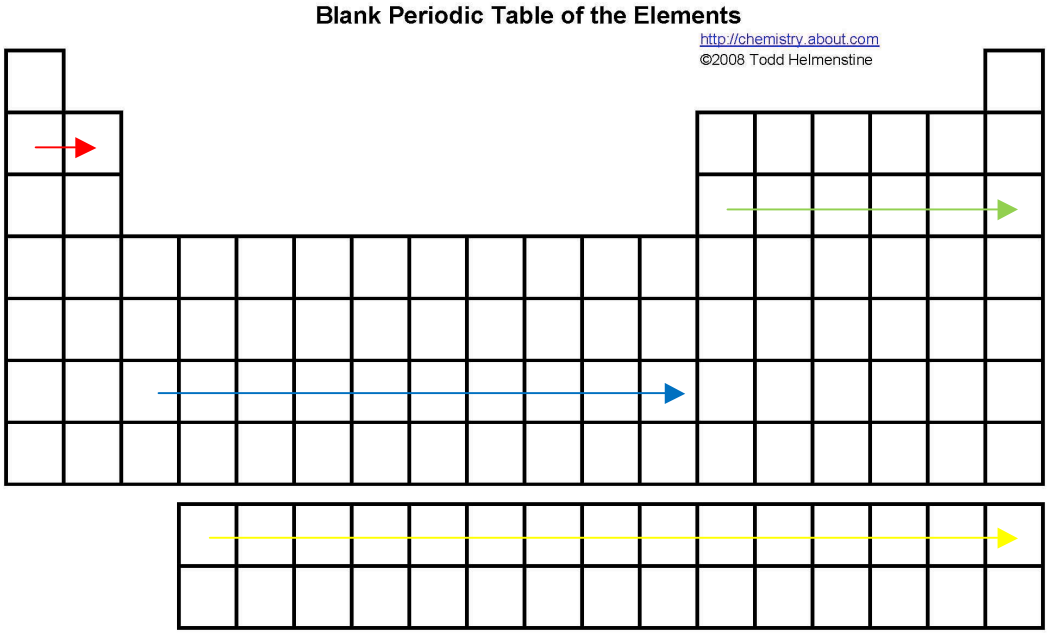
6. **PERIODICITY** (6 points) - Using the afbau principle, the following orbital configurations were identified. Predict the ionic charge for each configuration.
   a. $1s^2 2s^2 2p^4$
      (-2)
   b. $1s^2 2s^2 2p^6$

(0)

c. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

(+1)

7. **PERIODICITY** (8 points) - Locate and uniquely mark on the periodic table below where you would be able to find elements with outermost:
   a. 5d orbitals **(transition period 6)**
   b. 3p orbitals **(period 3, group 3A to 8A)**
   c. 2s orbitals **(period 2, group 1A to 2A)**
   d. 4f orbitals **(Lanthanide series)**



8. **PERIODICITY** (8 points) - Indicate whether each statement is true (T) or false (F).
   a. **F** The first ionization energies for Group 1A elements increase with increasing molecular weight.
   b. **T** The first ionization energies for the Period 2 elements increase with increasing molecular weight.
   c. **F** The atomic radii increase with increasing molecular weight across a period.
   d. **F** The atomic radii decrease with increasing molecular weight down a group.
   e. **T** In general, the electronic affinity increases from left to right.
   f. **F** Electronegativity increases from left to right on the periodic table (across Groups 1A to 8A) and top to bottom (from Periods 1 to 7).
   g. **T** When two atoms bond, the greater the electronegativity difference the more ionic the bond.

h. **T** When two atoms of the same element bond, the electronegativity difference is zero and the bond can be identified as polar covalent.

9. **PERIODICITY** (2 points) - First ionization energy refers to (check all that apply):
   - **X** Removal of an electron from a gas atom.
   - _____ Energy to form the most probable ion.
   - _____ Trapping an ion in a lattice structure.
   - _____ Formation of a -1 anion.

10. **PERIODICITY** (2 points) - From the periodic table, predict the molecular formula of silicon (Si) oxide (O).

    SiO_2

11. **PERIODICITY** (2 points) - The formula for potassium aluminum sulfate is (not including water of hydration):

    $KAl(SO_4)_2$

12. **PERIODICITY** (2 points) - The name of $(NH_4)_2Cr_2O_7$ is:

    Ammonium dichromate

13. **PERIODICITY** (2 points) - Two metals, both of which commonly form +1 and +2 ions in solution are:

    - **X** Cu and Hg
    - _____ Au and Ag
    - _____ Fe and Cu
    - _____ Zn and Cd

14. **PERIODICITY** (2 points) - Metals have: (check all that apply)

X Both high electrical and high thermal conductivity.

_____ High electrical but low thermal conductivity.

_____ Low cohesive strength and high luster.

_____ High luster and low ductility.

15. **PERIODICITY** (2 points) - Nonmetals are: (check all that apply)

_____ Malleable but not ductile.

_____ Very reactive with acids.

_____ Good conductors of electricity.

X Able to form halides which react with water to give an oxyacid.

16. **PERIODICITY** (2 points) - Halogens: (check all that apply)

_____ Will not react with each other

_____ Are strong electron donors

X Form strong oxyacids of the formula HX_3O

_____ Form strong covalent bond with Group 1A metals

17. **EQUILIBRIUM** (2 points) - When the same ion is produced by two different components, the common ion effect takes place. By adding salt containing a weak acid's conjugate base into solution, the dissociation of the weak acid will _____ and the pH will _____ according to Le Châtelier's Principle.

_____ Increase, Increase

_____

_____ Decrease, Decrease

_____ Increase, Decrease

X Decrease, Increase

18. **EQUILIBRIUM** (2 points) - Buffers work by applying Le Châtelier's Principle to weak acid equilibrium. Buffer solutions contain significant amounts of the weak acid molecules, HA and its conjugate base A^{-1}. These molecules react with added acid or base to neutralize it:

$$HA(aq) \rightarrow A{-}(aq) + H^{+}(aq)$$

When adding a strong acid or a strong base to the buffer solution represented above,

X The added H^+ will decrease the conjugate weak base and increase the weak acid concentration.

_____ The added H^+ will increase the conjugate weak base and increase the weak acid concentration.

_____ The added OH^- will decrease the conjugate weak base and increase the weak acid concentration.

_____ The added OH^- will increase the conjugate weak acid and decrease the weak base concentration.

19. **EQUILIBRIUM** (2 points) - For insoluble ionic hydroxides (as shown in the equation below), the _____(lower, higher) the pH, the _____ (lower, higher) the solubility.

$$M(OH)n(s) \leftrightarrow Mn{+}(aq) + n OH{-}(aq)$$

Lower, Higher

20. **EQUILIBRIUM** (4 points) - The reaction for the dissociation of water results in the generation of hydronium ions and hydroxide ions. The equilibrium constant for this reaction at 25°C is 1.00×10^{-14}, and the enthalpy of the reaction is 55.81 kJ/mol. Estimate the activity of OH^- in a solution at 25°C and one at 4°C, if $\{H^+\}=10^{-7}$ in both solutions.

$$\boldsymbol{ln\ \frac{K_{eq_{4°C}}}{K_{eq_{25°C}}} = \frac{\Delta H_r}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right) = \frac{55.81\ kJ/mol}{8.314\times10^{-3}kJ/(mol-K)}\left(\frac{1}{298K} - \frac{1}{277K}\right) = -1.71}$$

$$\boldsymbol{K_{eq_{4°C}} = 1.8\times10^{-15}}$$

21. **EQUILIBRIUM** (4 points) If a solution contains 4.2 x 10^{-6} M silver ions, does a precipitate form? (K_{sp}(AgCl) = 1.8x10^{-10})

$Q_{sp} = [Ag^+][Cl^-] = (4.2x10^{-6})(4.2x10^{-6}) = 1.76x10^{-11}$
$Q_{sp} < K_{sp}$, no precipitate will form.

22. **EQUILIBRIUM** (10 points) - Phosphorus pentachloride (PCl_5) decomposes to phosphorus trichloride (PCl_3) and chlorine gas when heated. The equilibrium constant for this reaction is 0.030 at 250°C. The solution initially contains only PCl_5 with a solution density of 20.8 g/L.

a. Write the equilibrium reaction.

$PCl_5(g) \leftrightarrow PCl_3(g) + Cl_2(g)$

b. What is the initial molar concentration of the PCl_5 solution?

20.8 g/L * (208.22 g/mol)$^{-1}$ ~ 0.1 M

c. At equilibrium, what are the concentrations of:

a) PCl_5
0.058 M

b) PCl_3
0.042 M

c) Cl_2
0.042 M

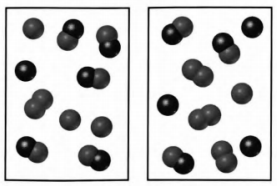
Solution

$$\frac{[\Delta][\Delta]}{[0.100 - \Delta]} = 0.030$$

$[PCl_5] = 0.100 - 0.042 = 0.058\ M$

$[PCl_3] = [Cl_2] = 0 + 0.042 = 0.042\ M$

23. **EQUILIBRIUM** (6 points) - The diagrams below show mixtures containing A atoms (gray), B atoms (black), A_2 molecules and AB molecules at 300 K (diagram a) and 500 K (diagram b). Is the reaction exothermic or endothermic?



(a) (b)

Diagram (a), 300 K:

$[A] = 3\ M, [AB] = 5\ M, [A_2] = 1\ M, [B] = 1\ M$

$$K_c = \frac{[A]\,[AB]}{[A_2]\,[B]} = \frac{(3)\,(5)}{(1)\,(1)} = 15$$

Diagram (b), 500 K:

$[A] = 1\ M, [AB] = 3\ M, [A_2] = 3\ M, [B] = 3\ M$

$$K_c = \frac{[A]\,[AB]}{[A_2]\,[B]} = \frac{(1)\,(3)}{(3)\,(3)} = 0.333$$

Since K_c **decreases** as **T increases** (move in opposite directions) this means the reaction is **exothermic** (shifts to left, reverse direction, as temp. inc.).

Show work (4 pts)
Exothermic (2 pts)

24. **EQUILIBRIUM** (6 points) - When 1.0 mole of acetic acid is diluted to a volume of 1.0 L, the acid ionizes to form acetate ions and hydronium ions. At equilibrium, 0.42% of the acetic acid is ionized. What percentage of the acid ionizes when 2.0 moles of acetic acid is diluted to 1.0 L? **_____0.3%____**

25. **EQUILIBRIUM** (4 points) - Given the following equilibrium constants, find pK_{eq} for the reaction.

$$HOCl + NH_3 \leftrightarrow NH_4^+ + OCl^-$$

Where,

$$HOCl + H_2O \leftrightarrow H_3O^+ + OCl^- \quad (K_{a,HOCl} = 10^{-7.6})$$

$$NH_4^+ + H_2O \leftrightarrow NH_3 + H_3O^+ \quad (K_{a,NH4+} = 10^{-9.25})$$

$K_{eq} = K_{a,HOCl} / K_{a,NH4+} = 10^{1.65}$

$pK_{eq} = -\log 10^{1.65} = -1.65$

26. **EQUILIBRIUM** (6 points) - Bismuth sulfide (Bi_2S_3) was placed in contact with water and in the course of equilibrium reaction dissolves into bismuth and sulfide ions. Its measured solubility is 1.0×10^{-15} mol/L at 25°C. Calculate the solubility product.

$K_{sp} = [Bi^{3+}]^2[S^{2-}]^3$

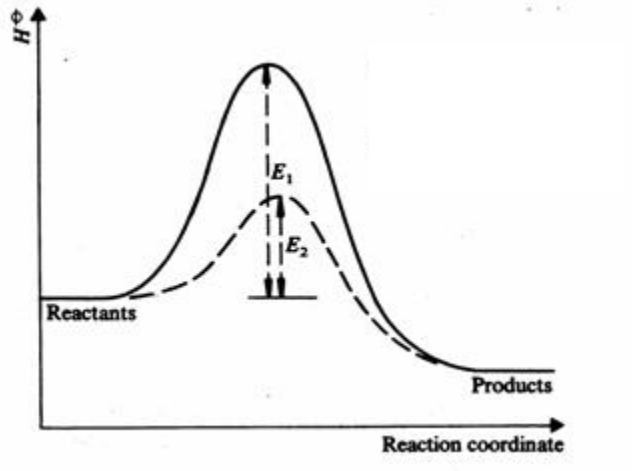
$Bi_2S_3\,(s) \leftrightarrow 2Bi^{3+}(aq) + 3S^{2-}(aq)$ (2 points)

$[Bi^{3+}]_0, [S^{2-}]_0 = 0$

$(1.0x10^{-15})Bi2S3\,(s) \leftrightarrow 2(1.0x10^{-15})\ Bi^{3+}(aq) + 3(1.0x10^{-15})\ S^{2-}(aq)$

$K_{sp} = (2.0x10^{-15})^2(3.0x10^{-15})^3 = 1.1x10^{-73}$ (3 points)

27. **EQUILIBRIUM** (4 points) - Consider the following diagram. One curve illustrates a catalytic reaction and one illustrates a non-catalytic reaction.



Which of the following statements are true (check all that apply)?

X E_1 illustrates the energy required to progress a reaction without a catalyst and E_2 illustrates the energy required to progress a catalyzed reaction.

_____ E_1 illustrates the energy required to progress a catalyzed reaction and E_2 illustrates the energy required to progress a reaction without a catalyst.

_____ Progression of the reactions is endothermic.

X Progression of the reactions is exothermic.

_____ The reactions need more energy to proceed along the reaction coordinate (left to right).

X The reactions need more energy to proceed against the reaction coordinate (right to left).

END OF TEST PORTION

EQUILIBRIUM - Lab Portion A (Total 20 points)

Please read the whole lab before starting this lab. You may have to answer questions during certain steps in the procedures below.

Procedures:

1. Put 10 drops of copper(II) sulfate solution into test tubes A and B.
2. Add ammonia solution drop-by-drop to test tube B. Shake the tube gently from side to side after each drop (4-5 drops). (see Question 2)
3. Continue to add ammonia drop-by-drop into test tube B until the solution is clear blue (4-5 more drops). (see Question 3)
4. Pour half of the clear blue solution in test tube B into test tube C.
5. Add sulfuric acid drop-by-drop to test tube C until you noticed a marked change in the solution. Shake the tube gently from side to side after adding each drop. (see Question 4)

Questions:

1. Provide the reaction that is occurring in test tube A as ammonia is added to the copper sulfate solution.
   $CuSO_4(aq) + 2NH_3(aq) + 2H_2O(l) \rightarrow Cu(OH)_2(s) + (NH_4)_2SO_4(aq)$ (5 points)

2. What happens in the solution in Step 2 of the Procedures? Predict the products.
   Precipitation of copper hydroxide. (3 points)
   OR
   Pale blue precipitate forms. (2 point)

3. What predictions can you make about what is occurring as you continue to add ammonia to test tube A?
   Reaction of copper hydroxide with additional ammonia results in complexation of copper hydroxide into aqueous copper amine ions, resulting in darker blue solution. (5 points)
   OR
   Solution becomes darker blue. (3 point)

4. As you continue to add acid to test tube B, predict the end products as the reaction proceeds. Provide the reaction that occurs in Step 5.

The reaction will re-dissolve the precipitate and re-generate a copper (II) sulfate solution. Shift the equilibrium to the left. (2 points)

$Cu(OH)_2(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + 2H_2O$ (5 points)

PERIODICITY – Lab Portion B (Total 20 points)

Please read the whole lab before starting this lab. You may have to answer questions during certain steps in the procedures below.

Procedures:

1. Pour 10 mL of the unknown solution A in a test tube. (Question 1)
2. Add 5 drops of Phenolphthalein. (Question 2)
3. Place the thermometer in the test tube as you stir in the unknown solid 1. (Question 3)

Questions:

1. Record the following observations from Step 1:
    a. Color
    Clear liquid (1 point)
    b. pH
    Accept any answer less than 6 (1 point)
    c. Temperature
    25°C (give or take) (1 point)

2. What is the color of the solution when you added Phenolphthalein in Step 2? What conclusions can you make about unknown solution A?

    Colorless. (1 point)
    Unknown solution A is not basic or a very weak base OR is a weak acid. (2 point)

3. Record the following observations after the solution has equalized in Step 3:
    a. Color
    Pink (1 point)
    b. pH
    Accept any answer greater than 8 (1 point)
    c. Temperature
    Accept any less than 25°C (1 point)
    d. Other noticeable changes
    Generation of gas bubbles in solution. (2 point)

4. Based on your observations on the change in temperature of unknown solution A during the addition of unknown solid 1, would you say the reaction is endothermic or exothermic?

Endothermic (2 points)

5. What type of chemical reaction occurred? Present the basis for your hypothesis using your observations in Questions 1-3.

Endothermic reaction (as temperature decreases with reaction). (1 point)

Neutralization reaction of weak acid solution as a solid base is added to it (generation of bubbles, change of pH from <7 to >7). (3 points)

Excess base generates a solution that is now basic (final pH is >7 and phenolphthalein indicator results in pink solution). (3 points)

END OF LAB PORTION