Exam 4

# Part 1: Multiple Choice (2 points each)

## Directions: Please circle the *best* answer for each of the following questions.

1. A student should attempt to use a fire extinguisher
	1. only if an instructor says it is okay.
	2. always, before sounding an alarm or alerting anyone else.
	3. only if the fire is small enough and the student can confidently use the available extinguisher.
	4. on all fires, no matter how small or large because the fire will certainly get larger and cause considerable damage.
	5. all of the above
2. When considering the vapor pressure of pure water and seawater at constant temperature, which of the following statements are correct?
	1. Water will have a higher vapor pressure than seawater.
	2. Seawater will have a lower vapor pressure than water.
	3. An increase in the van’t Hoff factor of a solute would decrease the vapor pressure of the solution.
	4. all of the above
	5. none of the above

1. Which one of the ionic compounds below would you expect to have the smallest (least negative) lattice energy?
2. MgF2
3. MgCl2
4. MgBr2
5. MgI2
6. CaI2
7. Suppose you have a 1.00 M aqueous solution of each of the following solutes: glucose (C6H12O6), sodium chloride, and acetic acid. Which solution has the highest pressure requirement for reverse osmosis?
	1. Sodium chloride
	2. Acetic acid
	3. Glucose
	4. Acetic acid and glucose
	5. all of the above
8. Ionic solids have \_\_\_\_\_\_\_\_ melting points, and are \_\_\_\_\_\_\_\_.
	1. high; malleable
	2. high; brittle
	3. low; malleable
	4. low; brittle
	5. high; soft
9. The 1987 Nobel Prize in physics was awarded to G. Bednorz and K. A. Mueller for their discovery of superconducting materials such as YBa2Cu3O7. What is another chemical formula for this compound?
	1. YBa2Cu3O9
	2. YBaCuO
	3. YBa2Cu3O7
	4. Y2Ba2Cu2O2
	5. Y0.5Ba3CuO
10. At a historic Civil War battleground, a stack of cannonballs looked like the picture below on the far left. Removing the top cannonball resulted in the middle view, and removing the next layer resulted in the view on the right. What sort of packing was used in stacking the cannonballs?
	1. cannonball closest-packed
	2. hexagonal closest-packed
	3. cubic closest-packed
	4. random-packed
	5. body-centered closest-packed
11. Solid mercury(II) oxide decomposes when heated to produce liquid mercury and oxygen.

2HgO(*s*)  2Hg(*l*) + O2(*g*)

An amount of mercury(II) oxide is placed in a vessel at a particular temperature and allowed to reach equilibrium. How could the amount of liquid mercury in the vessel be increased?

I. Adding more mercury(II) oxide.

II. Removing some oxygen.

III. Increasing the volume of the vessel.

* 1. I only
	2. II only
	3. III only
	4. I and II
	5. II and III
1. For the chemical equilibrium aA +bB  cC, the value of the equilibrium constant, *K*, is 10. What is the value of the equilibrium constant for the following reaction? **cC  **aA + **bB
2. 0.32
3. 10
4. 3.2
5. 3.1
6. 32
7. A chemical equilibrium may be established by starting a reaction with \_\_\_\_\_\_\_\_
8. reactants only.
9. products only.
10. equal quantities of reactants and products.
11. any quantities of reactants and products.
12. all of the above.

# Part 2: Short Answer

## Directions: Answer each of the following questions. Be sure to use complete sentences where appropriate. For full credit be sure to show all of your work.

1. Use the Born-Haber cycle to calculate the lattice energy of calcium oxide. The enthalpy of formation of calcium oxide is -634.9 kJ/mol, the first and second ionization energies of calcium are 590 kJ/mol and 1145 kJ/mol respectively, the enthalpy of sublimation of calcium is 178 kJ/mol. The bond energy of oxygen gas is 498 kJ/mol, the first and second electron affinities of an oxygen atom are are -141 kJ/mol and 744 kJ/mol respectively (10 points).

Ca2+ (g) + O2- (g) 🡪 CaO (s) ∆Hlattice = ?

Ca (g) 🡪 Ca+ (g) + 1 e- ∆Hie1 = 590 kJ/mol

Ca+ (g) 🡪 Ca2+ (g) + 1 e- ∆Hie2 = 1145 kJ/mol

Ca (s) 🡪 Ca (g) ∆Hsub = 178 kJ/mol

(O2 (g) 🡪 2 O(g) ∆H = 498 kJ/mol) **x ½**

O (g) + 1 e- 🡪 O- (g) ∆Hea1 = -141 kJ/mol

O- (g) + 1 e- 🡪 O2- (g) ∆Hea2 = 744 kJ/mol

 Ca (s) + ½ O2 (g) 🡪 CaO (s) ∆Hf = -634.9 kJ/mol

∆Hlattice = -634.9 kJ/mol -590 kJ/mol – 1145 kJ/mol – 178 kJ/mol - ½(498 kJ/mol) + 141 kJ/mol -744 kJ/mol

∆Hlattice = -3,400. kJ/mol

1. Gold has a face-centered cubic structure with a unit cell edge length of 407.8 pm (12 points).
	1. What is the contribution to the density from each individual gold atom?

$$D=\frac{m}{V}=\frac{m}{l^{3}}$$

$$D=\frac{196.967\frac{g}{mol}×\frac{1 mol }{6.022×10^{23} atoms}×\frac{4 atoms}{unit cell }}{\left(407.8 pm×\frac{1 m}{10^{12} pm}×\frac{100 cm}{1 m}\right)^{3} }=19.29172427\frac{g}{cm^{3}}≈19.29\frac{g}{cm^{3}}$$

* 1. If the actual density of gold is 19.30 g/cm3, what is the percent error?

$percent error=\frac{observed value-accepted value}{accepted value}×100$

$$percent error=\frac{19.29\frac{g}{cm^{3}}-19.30\frac{g}{cm^{3}}}{19.30\frac{g}{cm^{3}}}×100=$$

$$percent error=\frac{-0.01 \frac{g}{cm^{3}} }{19.30 \frac{g}{cm^{3}}}×100$$

$$percent error=-0.051813472\%≈-0.05\%$$

1. Complete the following sentences about semiconductors (2 points):
	1. When Si is doped with P, it produces a(n) \_\_\_\_n\_\_\_\_-type semiconductor.
	2. When Ge is doped with Ga, it produces a(n) \_\_\_p\_\_\_\_\_-type semiconductor.
2. An elemental analysis of adrenaline is 59.0% C, 7.10% H, 7.60% N, and 26.2% O by mass (15 points).
	1. What is the empirical formula?

$$59.0 g C×\frac{1 mol C}{12.011 g C}=4.91216385 mol C$$

$$7.10 g H×\frac{1 mol H}{1.008 g H}=7.043650794 mol H$$

$$7.60 g N×\frac{1 mol N}{14.007 g N}=0.5425858499 mol N$$

$$26.2 g O×\frac{1 mol O}{15.999 g O}=1.63760235 mol O$$

$$C\_{\frac{4.91216385 mol}{0.5425858499 mol}}H\_{\frac{7.043650794 mol}{0.5425858499 mol}}N\_{\frac{0.5425858499 mol}{0.5425858499 mol}}O\_{\frac{1.63760235 mol}{0.5425858499 mol}}$$

$$C\_{9.053247243}H\_{12.98163377}N\_{1}O\_{3.018144226}≈C\_{9}H\_{13}NO\_{3}$$

* 1. What is the empirical mass? \_\_\_\_\_\_\_183.207 g/mol
	2. When 0.64 g of adrenaline was dissolved in 36.0 g benzene, kf = 5.12 ˚C/*m*, the freezing point decreased by 0.50 ˚C. What is the molar mass?

$$MM=\frac{m}{n}=\frac{m\_{solute}}{∆T\_{f}}×\frac{ik\_{f}}{m\_{solvent}}$$

$$MM=\frac{0.64 g}{0.50 ℃}×\frac{\left(1\right)\left(5.12 ℃\frac{kg solvent}{mol solute}\right)}{36.0 g solvent}×\frac{1000 g}{1 kg}=182.0444\frac{g}{mol}≈180\frac{g}{mol}$$

* 1. What is the molecular formula? \_\_\_\_\_\_C9H13NO3
1. Minnesotaite [Fe3Si4O10(OH)2] is a silicate mineral with a layered structure similar to that of kaolinite. The distance between the layers in minnesotaite is 1940 ± 10 pm. What is the smallest angle of diffraction of X-rays with λ = 154 pm from this solid (5 points)?

$$λ=2dsinθ⇒θ=sin^{-1}\left(\frac{λ}{2d}\right)=sin^{-1}\left(\frac{154 pm}{2(1940 pm)} \right)=2.274708348°≈2.27°$$

1. You like boiled eggs for breakfast, but they take too long to cook, and you are always late to your early morning class. Lucky you! You have learned that adding table salt, NaCl (2.16 g/cm3), to water (*K*b = 0.52°C/m) increases the temperature at which it boils. You figure that you can cook eggs faster at a higher temperature in boiling salty water! If you add 4 tablespoons (1 tbsp = 14.8 cm3) of salt to 16 oz of water (474 mL, 16 oz ≡ 1 lb) (10 points).
	1. What is the molality of the solution?

$$m=\frac{n\_{solute}}{kg\_{solvent}}$$

$$m=\frac{4 tbsp NaCl}{16 oz water}×\frac{14.8 cm^{3}}{1 tbsp}×\frac{2.16 g NaCl}{1 cm^{3} NaCl}×\frac{16 oz}{1 lb}×\frac{2.2046 lb}{1 kg}×\frac{1 mol NaCl}{58.443 g NaCl}$$

$$m= \frac{mol NaCl}{kg H\_{2}O}=4.476603049 m NaCl≈4.48 m NaCl $$

* 1. What increase in the boiling point do you expect?

$$∆T\_{b}=ik\_{b}m$$

$$∆T\_{b}=\left(2\right)\left(0.52 \frac{℃}{m}\right)\left(4.48 m NaCl\right)=4.6755667171 ℃≈4.7℃$$

1. For the equilibrium: C (s) + 2 H2 (g) $⇌$ CH4 (g) + heat

For each of the following changes to the system at equilibrium, predict the direction of the shift and explain why it occurs (8 points):

|  |  |  |
| --- | --- | --- |
| **Change**  |  **Shift**  | **Reason** |
| The volume of the reaction vessel is doubled. | **left** | **Volume change causes P to drop. Shift left makes more moles of gas and therefore a higher pressure** |
| The temperature is increased. | **left** | **shifts left to use up heat** |
| The pressure of H2 (g) is increased. | **right** | **Shifts to the right to decrease the moles of H2. Reaction rate to right increases, to the left stays the same so there is a net shift to the right.** |
| Adding a catalyst | **no change** | **A catalyst does not affect the position of the equilibrium. (So then, just what does it do?)** |

1. The reaction 2 NO (g) + Br2 (g) $⇌$ 2 NOBr (g) has a Kp = 1.17 atm−1 at 25oC (18 points).
	1. If 1.10 atm of NOBr, 0.100 atm of NO, and 0.0100 atm of Br2 are mixed at 25oC, what reaction will occur? Explain.

$$Q=\frac{[NOBr]^{2}}{[NO]^{2}[Br\_{2}]}=\frac{(1.10 atm)^{2}}{(0.100 atm)^{2}(0.01 atm)}=12100 atm^{-1}$$

 Q > K, therefore the reaction will proceed to the left.

* 1. When 5.00 atm of NOBr is allowed to equilibrate at 50oC, the equilibrium pressure of NOBr is measured to be 4.30 atm. What is the value of Kp at 50oC? Compare with the value of Kp at 25oC and explain.

|  |  |  |  |
| --- | --- | --- | --- |
|  | 2 NO (g) + | Br2 (g) $⇌$ | 2 NOBr (g) |
| I | 0 atm | 0 atm | 5.00 atm |
| C | +2x | +x | -2x |
| E | 2x = 2(0.35 atm) =0.70 atm | x = 0.35 atm  | 5.00 atm – 2x = 4.30 atm |

$$K\_{p}=\frac{[NOBr]^{2}}{[NO]^{2}[Br\_{2}]}=\frac{(4.30 atm)^{2}}{(0.70 atm)^{2}(0.35 atm)}=107.8134111 atm^{-1}≈108 atm^{-1} $$

The Kp increases as the temperature is increased. This means the reaction shifts to the right when heat is added so it is an endothermic reaction.

* 1. What is the value of Kc at 50 °C?

$$K\_{p}=K\_{c}(RT)^{Δn}⟹K\_{c}=\frac{K\_{p}}{(RT)^{Δn}}=\frac{108 atm^{-1}}{\left[\left(0.0821 \frac{L atm}{mol K}\right)\left(50 °C+273\right)\right]^{\left(2-2-1\right)}}=2860\frac{L}{mol}$$