

## Spring 2009 CH302 Practice Exam 1 Answer Key

1. In general, increasing the temperature favors which phase changes?

1. sublimation, vaporization, fusion **\*correct\***
2. sublimation, vaporization, condensation
3. fusion, vaporization, deposition
4. vaporization, freezing, deposition
5. freezing, deposition, condensation

Explanation: Phase changes are equilibrium processes. liquid to gas, solid to gas, and solid to liquid phase change processes are endothermic and require a gain of heat, since each new phase has more internal energy. Adding heat shifts the reaction to favor these processes. Exothermic processes (the reverse phase changes) lose heat/energy to undergo those transitions.

2. Vapor pressure:

- A. Is an equilibrium process
  - B. increases as IMF increases
  - C. is temperature dependent
  - D. is higher in  $\text{CH}_3\text{CH}_3$  than  $\text{H}_2$
  - E. decreases with the addition of solutes
  - F. depends on the whole volume of the liquid
  - G. decreases at temp increases
1. A, C, E, G
  2. A, B, C, E
  3. A, C, D, E
  4. B, D, F, G
  5. A, C, E **\*correct\***
  6. A, C, E, F

Explanation: Vapor pressure is an equilibrium process that occurs only at the surface area of the liquid. The VP decreases with the presence of solutes because they will also take positions at the surface of the mixture, thus decreasing the surface area of the liquid. This is VP depression. Additionally, as IMF increases, VP decreases, since those IMF's are intermolecular attractions that are keeping the liquid intact. These require energy to be broken, so evaporation is less spontaneous. Ethane is larger than hydrogen, so it will have a lower vapor pressure (size does matter).

3. Rank the following in decreasing order of solubility in water:

$\text{Mg}(\text{OH})_2$ ,  $\text{NaCl}$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{CsI}$ ,  $\text{BeBr}_2$ ,  $\text{KOH}$ ,  $\text{BaO}$ .

1.  $\text{Al}_2\text{O}_3 > \text{BaO} > \text{Mg}(\text{OH})_2 > \text{BeBr}_2 > \text{KOH} > \text{NaCl} > \text{CsI}$
2.  $\text{NaCl} > \text{CsI} > \text{KOH} > \text{BeBr}_2 > \text{Mg}(\text{OH})_2 > \text{BaO} > \text{Al}_2\text{O}_3$
3.  $\text{Al}_2\text{O}_3 > \text{BaO} > \text{Mg}(\text{OH})_2 > \text{BeBr}_2 > \text{KOH} > \text{NaCl} > \text{CsI}$
4.  $\text{CsI} > \text{NaCl} > \text{KOH} > \text{BeBr}_2 > \text{Mg}(\text{OH})_2 > \text{BaO} > \text{Al}_2\text{O}_3$  **\*correct\***
5.  $\text{NaCl} > \text{CsI} > \text{BeBr}_2 > \text{KOH} > \text{Mg}(\text{OH})_2 > \text{BaO} > \text{Al}_2\text{O}_3$
6.  $\text{CsI} > \text{NaCl} > \text{BeBr}_2 > \text{KOH} > \text{Mg}(\text{OH})_2 > \text{BaO} > \text{Al}_2\text{O}_3$

Explanation: Solubility in water will depend on the crystal lattice energy of the salt. Rank the salts based on their charge densities.  $\text{CsI}$  has a lower charge density than  $\text{NaCl}$ , and its ionic bond is much weaker.  $\text{KOH}$  is next because it is still in the +1,-1 charge category, but now there is the ionic bond and additional H-bonds (from the OH) that much be broken for this salt to dissolve.  $\text{BeBr}_2$  has a greater solubility than  $\text{Mg}(\text{OH})_2$  for the same reason. Though an oxide,  $\text{BaO}$  has a much weaker charge density than  $\text{Al}_2\text{O}_3$ .

4. According to the given phase diagram for carbon, how many triple points are there? What would you expect to see at 0.01GPa, 4500K?

1. 5; metastable liquid, graphite and liquid
2. 4; graphite, metastable liquid and vapor. **\*correct\***
3. 5; vapor, metastable liquid, graphite.
4. 4; graphite, liquid, diamond.
5. 3; graphite, metastable liquid and vapor.

Explanation: The triple point is the place where three lines (phases) intersect, and at that point, each of those phases is present. There are only 4 here, the point at 10.0 GPa does not count...there is crazy stuff going on there. There are three down where liquid, graphite, vapor and metastable liquid are interacting. The fourth is around 10000K:100GPa, where diamond, liquid and metal interface.

5. According to the given pressure-temperature diagram, a sample of carbon at 0.005GPa and 2000K is graphite. This sample is then heated to 7000K at constant pressure. Then, at constant temperature, the sample is compressed to 1.00GPa. Again, at constant pressure, the temperature is decreased to 1000K. At this temperature, the pressure is increased to 500GPa. How many phase transitions has the carbon sample undergone?

1. 6 **\*correct\***
2. 4
3. 1
4. 5
5. 7

Explanation: Navigating through the pressure-temperature diagram while the sample undergoes the stated manipulations, it starts out as graphite. Then, it is heated to vapor, compressed to liquid, cooled back to graphite and finally to graphite+metastable diamond. Lastly, it is compressed further to diamond+metastable graphite and finally to diamond. Six transitions total.

6. How much heat is generated when 10g steam at 115 °C is cooled to -75 °C?

$C_{\text{ice}} = a \text{ J/g } ^\circ\text{C}$ ;  $C_{\text{water}} = b \text{ J/g } ^\circ\text{C}$ ;  $C_{\text{steam}} = c \text{ J/g } ^\circ\text{C}$ ;  $\Delta H_{\text{vap}} = d \text{ J/g}$ ;  $\Delta H_{\text{fus}} = e \text{ J/g}$ .

1.  $q = - [150(5a + c) + 10(100b + d + e)] \text{ J}$  **\*correct\***
2.  $q = [150(5a + c) + 10(100b + d + e)] \text{ J}$
3.  $q = -[150(a + c) + 10(100b + d + e)] \text{ J}$
4.  $q = [150 (a + c) + 1000b] \text{ J}$
5.  $q = - [150 (5a + c) + 1000b] \text{ J}$

Explanation: Cooling steam from 115 °C to 100 °C,  $\Delta H = m c_{\text{steam}} \Delta T = 10\text{g} \times c \times 15 \text{ } ^\circ\text{C} = 150c \text{ J}$ . Changing steam to water at 100 °C (the boiling point of water),  $\Delta H = m \Delta H_{\text{vaporization}} = 10\text{g} \times d = 10d \text{ J}$ . Cooling water at 100 °C to water at 0 °C,  $\Delta H = m c_{\text{water}} \times 100 \text{ } ^\circ\text{C} = 1000b \text{ J}$ . Changing water to ice at 0 °C (the freezing point of water),  $\Delta H = m \Delta H_{\text{fusion}} = 10\text{g} \times e = 10e \text{ J}$ . Finally, cooling ice from 0 °C to -75 °C,  $\Delta H = m c_{\text{ice}} \Delta T = 10\text{g} \times a \times 75 \text{ } ^\circ\text{C} = 150(5a) \text{ J}$ . Adding everything together, the  $\Delta H_{\text{sys}}$  for the entire process is  $[150(5a + c) + 10(100b + d + e)] \text{ J}$ . Since the system is losing heat, the sign is negative.  $\Delta T = 10\text{g} \times$

7. Which solvent would you expect BH<sub>3</sub> gas to be most soluble in?

1. C<sub>6</sub>H<sub>6</sub> **\*Correct\***
2. H<sub>2</sub>O
3. CH<sub>3</sub>CH<sub>2</sub>OH
4. CH<sub>2</sub>Cl<sub>2</sub>
5. N(CH<sub>3</sub>)<sub>3</sub>

Explanation: BH<sub>3</sub> is a non-polar gas. According to like dissolves like, it will be most soluble in a non-polar solvent. Benzene (C<sub>6</sub>H<sub>6</sub>) is the only non-polar solvent here. If you are unsure about any of them, draw the lewis dot structures.

8. Rank the following in decreasing order of miscibility with water:  $\text{H}_2\text{O}_2$ ,  $\text{C}_6\text{H}_6$ ,  $\text{HOCH}_2\text{CH}_2\text{NH}_2$ ,  $\text{C}_2\text{H}_6\text{Cl}_2$ , and  $\text{CH}_3\text{CH}_2\text{CH}_2\text{SH}$ .

1.  $\text{H}_2\text{O}_2 > \text{HOCH}_2\text{CH}_2\text{NH}_2 > \text{CH}_3\text{CH}_2\text{CH}_2\text{SH} > \text{C}_2\text{H}_6\text{Cl}_2 > \text{C}_6\text{H}_6$
2.  $\text{HOCH}_2\text{CH}_2\text{NH}_2 > \text{H}_2\text{O}_2 > \text{C}_2\text{H}_6\text{Cl}_2 > \text{CH}_3\text{CH}_2\text{CH}_2\text{SH} > \text{C}_6\text{H}_6$
3.  $\text{H}_2\text{O}_2 > \text{HOCH}_2\text{CH}_2\text{NH}_2 > \text{C}_2\text{H}_6\text{Cl}_2 > \text{CH}_3\text{CH}_2\text{CH}_2\text{SH} > \text{C}_6\text{H}_6$  **\*correct\***
4.  $\text{C}_6\text{H}_6 > \text{CH}_3\text{CH}_2\text{CH}_2\text{SH} > \text{C}_2\text{H}_6\text{Cl}_2 > \text{HOCH}_2\text{CH}_2\text{NH}_2 > \text{H}_2\text{O}_2$
5.  $\text{C}_6\text{H}_6 > \text{CH}_3\text{CH}_2\text{CH}_2\text{SH} > \text{C}_2\text{H}_6\text{Cl}_2 > \text{H}_2\text{O}_2 > \text{HOCH}_2\text{CH}_2\text{NH}_2$

Explanation: following the rule "like dissolves like" small very polar molecules will be more soluble in water than non-polar ones. Hydrogen peroxide is most polar (and actually looks like water) and so its most soluble. Next is amino-ethanol since it has a small carbon chain and has can participate in 3 hydrogen bonds. Dichloroethane is next, due to the polar chlorine-carbon bonds. Then propanethiol, since there is only a small EN difference between S-H and C-S, followed by benzene which is completely non-polar.

9. At 25 C, the vapor pressure of pure benzene ( $\text{C}_6\text{H}_{10}$ ) is 0.1252 atm. Suppose 6.4 g of naphthalene,  $\text{C}_{10}\text{H}_8$ , is dissolved in 78 g of benzene (benzene's molar mass is 78 g/mol). Assuming ideal behavior, what is the vapor pressure of benzene over the solution?

1. 0.9525 atm
2. 0.119 atm **correct**
3. 0.1252 atm

Explanation: The moles of solvent (benzene),  $n_{\text{benzene}}$ , is 1.00. The number of moles of solute is found by dividing the mass of solute by molar mass of naphthalene. Calculating the mole fraction of benzen is found the following way:

$$X_{\text{benzene}} = n_{\text{benzene}} / (n_{\text{benzene}} + n_{\text{naphthalene}})$$

Using Raoult's Law, the vapor pressure of benzene is the initial pressure multiplied by the mol fraction of the solvent.

10. Water has a vapor pressure of 24 mmHg at 25 °C and a heat of vaporization of 40.7 kJ/mol. What is the vapor pressure of water at 67 °C?

1. 182 mmHg **correct**
- 2 3.15 mmHg
3. 760 mmHg
4. 0 mmHg

Explanation: Simply use the Clausius-Clapeyron Equation to figure out the vapor pressure. We have to be a bit careful about the units of R: the units we're using are kJ, so  $R = 8.31 \times 10^{-3} \text{ kJ/mol K}$ .

$$\ln(P_2/P_1) = -DH_{\text{vap}}/R * (1/T_2 - 1/T_1)$$

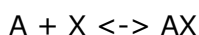
$$\ln(P_2/24) = 40.7 \text{ kJ}/8.31 \times 10^{-3} \text{ kJ/mol K} * (1/340 - 1/298)$$

$$\ln(P_2/24) = 2.03$$

$$P_2/24 = 7.62$$

$$P_2 = 182 \text{ mmHg}$$

11. For the following made-up reaction, where  $K_{200\text{K}} = 0.0035$  and  $K_{300\text{K}} = 0.38$ , solve for the enthalpy change for the reaction.



1.  $\Delta H = 23.3 \text{ kJ/mol}$

2.  $\Delta H = -48 \text{ kJ/mol}$

3.  $\Delta H = 48 \text{ kJ/mol}$

4.  $\Delta H = -23.3 \text{ kJ/mol}$  **CORRECT**

Explanation: Use the van't Hoff equation, but be careful about the signs and orders of equilibrium constants and temperatures. This is very important.

12. The vapor pressure is always less above the (pure solvent or dilute solution) than it is above the (pure solvent or dilute solution).

1. dilute solution, pure solvent **CORRECT**

2. pure solvent, dilute solution

Explanation: Since  $x_1 = 1 - x_2$ , Rault's Law can be written as  $\Delta P_1 = -x_2 P_1^*$ ; thus, the change in vapor pressure of the solvent (upon addition of solute) is proportional to the mole fraction of the solute. Thus, addition of solute will reduce the vapor pressure of the solvent.

13. If you add 45 g of NaCl to 500 g of water, what will the melting and boiling points be of the resulting solution? For liquid water,  $K_b = 0.52 \text{ C/m}$  and  $K_f = 1.86 \text{ C/m}$ . Answer should be in the form of (melting pt, boiling pt)

1. 101.6 C, 5.73 C

2. 5.73 C, 101.6 C

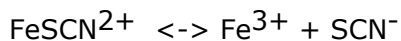
3. -5.73 C, 101.6 C **correct**

4. -5.73 C, 98.4 C

Explanation: First step is to calculate the molality of the solution. Do this by converting g of NaCl to mols via division by molar mass and dividing the result by the mass (in kg) of water. This gives  $m = 1.54m$ . Plugging into  $\Delta T = imK$ , and knowing that  $i=2$  for NaCl, gives the change in boiling point and freezing point for the water.  $\Delta T = 5.73 \text{ C}$  and  $\Delta T = 1.60 \text{ C}$  for melting and boiling temperature, respectively. Thus, the melting point (equivalent to freezing point) of the solution is  $-5.73 \text{ C}$  and the boiling point is  $101.6 \text{ C}$ . Remember the freezing point of pure water is  $0 \text{ C}$  and the boiling point of pure water is  $100 \text{ C}$ .

14. Iron thiocyanate ( $\text{FeSCN}^{2+}$ ) is a complex ion that appears orange-red in solution

Iron (III) and thiocyanate ions are both colorless in solution. All species are aqueous.



Set up the equilibrium expression for the reaction:

1.  $K = \frac{[\text{FeSCN}^{2+}]}{[\text{Fe}^{3+}] [\text{SCN}^-]}$

2.  $K = \frac{[\text{Fe}^{3+}] [\text{SCN}^-]}{[\text{FeSCN}^{2+}]}$  **correct**

3.  $K = \frac{[\text{Fe}^{3+}]^3 [\text{SCN}^-]}{[\text{FeSCN}^{2+}]^2}$

4.  $K = \frac{[\text{FeSCN}^{2+}]^2}{[\text{Fe}^{3+}]^3 [\text{SCN}^-]}$

Explanation: All species are aqueous, so all are included in the equilibrium expression K. Products in numerator, reactants in the denominator; all concentrations are raised to the first power, per their balanced-reaction coefficients.

15. For the decomposition of gaseous water into hydrogen and oxygen gas,  $K = 8 \times 10^{-41}$

With this information, is water a good source of oxygen at room temperature?

a) Yes

**b) No**

Explanation: NO, it is not. As an equilibrium constant approaches zero or infinity, the process can be increasingly thought of as irreversible. Since the K is so low for the decomposition, water is not a good source of oxygen gas at this temperature.

16. The gas-phase dissociation of phosphorus pentachloride to the trichloride has  $K_p = 3.60$  at  $540^\circ\text{C}$ :



What will be the partial pressures of all three components if 0.200 mole of  $\text{PCl}_5$  and 3.00 moles of  $\text{PCl}_3$  are combined and brought to equilibrium at this temperature?

1.  $P(\text{PCl}_5) = 2 \text{ atm}$ ,  $P(\text{PCl}_3) = 3 \text{ atm}$ ,  $P(\text{Cl}_2) = 0 \text{ atm}$
2.  $P(\text{PCl}_5) = 3.159$ ,  $P(\text{PCl}_3) = 1.41 \text{ atm}$ ,  $P(\text{Cl}_2) = 0.159 \text{ atm}$
3.  $P(\text{PCl}_5) = 0.41 \text{ atm}$ ,  $P(\text{PCl}_3) = 4.59 \text{ atm}$ ,  $P(\text{Cl}_2) = 1.59 \text{ atm}$
4.  $P(\text{PCl}_5) = 0.041 \text{ atm}$ ,  $P(\text{PCl}_3) = 3.159 \text{ atm}$ ,  $P(\text{Cl}_2) = 0.159 \text{ atm}$  **correct**

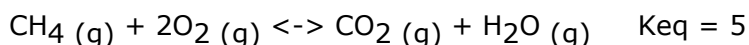
**Explanation:**

	$\text{PCl}_5$	$\text{PCl}_3$	$\text{Cl}_2$
initial moles:	0.200	3.00	0
change:	$-x$	$+x$	$+x$
equilibrium moles:	$0.200 - x$	$3.00 + x$	$x$

The partial pressures are found by multiplying the mole fraction of each gas by the total pressure:  $P_i = X_i P_t$ . The term in the denominator of each mole fraction is the total number of moles of gas present at equilibrium:  $(0.200 - x) + (3.00 + x) + x = 3.20 + x$ .

Substituting the equilibrium partial pressures into the equilibrium expression and rearranging gives a polynomial of form  $4.60 x^2 + 13.80 x - 2.304 = 0$ . Use the quadratic equation to solve for the roots of the polynomial.  $X = 0.159$  is the physically-meaningful root and substitution of this root into the expressions for the equilibrium partial pressures in the table yields the following values:  $P(\text{PCl}_5) = 0.41 \text{ atm}$ ,  $P(\text{PCl}_3) = 4.59 \text{ atm}$ ,  $P(\text{Cl}_2) = 0.159 \text{ atm}$ .

17. For the following reaction, the partial pressures of carbon dioxide, water, methane, and oxygen all are the same at equilibrium. What is their partial pressure?



1. 1 atm
2. 5 atm

3. 10 atm
4. 0.2 atm **Correct**
5. 0.1 atm

Explanation: The equation for equilibrium expression,  $K$ , is  $[(P_{H_2O})(P_{CO_2})]/[(P_{O_2})^2(P_{CH_4})]$ . Since all the partial pressures are equal,  $5 = x^2/x^3 = 1/x$ . Thus the partial pressure is 0.2 atm.

18. For the following reaction,  $C_4H_8(s) + 6O_2(g) \rightleftharpoons 4CO_2(g) + 4H_2O(g)$ ,  $K_{eq} = 10$  atm. The initial pressures of oxygen, carbon dioxide, and water are 1 atm, 0.5 atm, and 0.5 atm respectively. Which of the following is true for this system?

1. To approach equilibrium, the reaction must shift left
2. More butene ( $C_4H_8$ ) needs to be oxidized to reach equilibrium
3. A reagent that removes water vapor would help the system reach equilibrium faster
4. The reaction is now at equilibrium
5. **Both 2 and 3 are true** **Correct**

Explanation:  $Q = P_{H_2O}^4 P_{O_2}^4 / P_{O_2}^6$ , plugging in all values,  $Q = 0.5^4 \times 0.5 = 0.004$ . Thus  $Q \ll K$ . To approach equilibrium, the reaction must shift right, not left. Likewise, more butane must be oxidized. By removing water from the reaction, the reaction would be shifted right, helping the system to reach equilibrium faster.

19. For the reaction  $3A(g) + B(g) \rightleftharpoons C(s) + D(g)$ ,  $\Delta H = -100$  J. Which of the following would minimize the formation of C?

- I. Decreasing the volume of the container
  - II. Heating the reaction
  - III. Removing A from the reaction
  - IV. Performing the reaction at a very high altitude
1. I
  2. II
  3. III
  4. IV
  5. II and III
  6. **II, III, and IV** **Correct**
  7. All of the above

Explanation: There are 4 moles of gas (3 A and 1 B) on the left side of the reaction and 1 mole of gas on the right side of the reaction. Thus decreasing the volume of the container would increase the pressure, shifting the reaction to the right. Since the reaction is exothermic, heating it would shift the reaction to the left. Removing A from the left side would shift the reaction to the left to compensate for the loss. Performing the reaction at a high altitude (low atmospheric pressure) would shift the reaction to the side with more moles of gas (left). Since we want to minimize the formation of C, we want the reaction to shift to the left.

20. Consider the exothermic combustion of hydrogen,  $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{H}_2\text{O}(\text{l})$ . Which of the following would shift the reaction to the same direction?

- I. Continuously removing water from the reaction
  - II. Heating the reaction
  - III. Decreasing the size of the container
- 1. I and II
  - 2. I and III Correct**
  - 3. II and III
  - 4. None

Explanation: Removing water from the reaction would shift it to the right. Since the reaction is exothermic, heating the reaction would shift it to the left. Decreasing the size of the container would increase pressure, shifting the reaction to the right.

21. Which of the following gives the correct pair of equilibrium constant, K, and change in free energy,  $\Delta G$ ?

- 1.  $K = 3, \Delta G = 3 \text{ kJ/mol}$
- 2.  $K = 1, \Delta G = -1 \text{ kJ/mol}$
- 3.  $K = 0, \Delta G = 0 \text{ kJ/mol}$
- 4.  $K = 0.1, \Delta G = -5 \text{ kJ/mol}$
- 5.  $K = 5, \Delta G = -4 \text{ kJ/mol}$  Correct**

Explanation: Knowing the basic relationship between K and  $\Delta G$  ( $K > 1$  when  $\Delta G$  is negative;  $K < 1$  when  $\Delta G$  is positive;  $K = 1$  when  $\Delta G$  is zero), you should eliminate all choices except for 5. To confirm, plug in values into  $\Delta G = -RT \ln K$ .

22. The auto-protolysis of water:

- I. Produces more hydrogen ions at higher temperatures
- II. Produces more hydroxide ions at higher temperatures
- III. Explains why water can only have a pH of 7

1. I
2. II
3. III
- 4. I and II Correct**
5. I, II, and III

Explanation: The auto-protolysis is an endothermic process that produces more hydrogen and hydroxide ions at higher temperatures. It explains why water has a higher  $K_w$  at higher temperatures (hence why water has lower pH at high temperatures).

23. At 100 °C, the pH of water is 6.145, what is the  $K_w$  of water at this temperature?

1.  $1.00 \times 10^{-14}$
- 2.  $5.13 \times 10^{-13}$  Correct**
3.  $0.53 \times 10^{-14}$
4.  $8.81 \times 10^{-15}$
5.  $7.01 \times 10^{-16}$

Explanation:  $K_w = [H^+][OH^-] = [H^+]^2$ . Thus  $K_w = (10^{-6.145})^2 = 5.13 \times 10^{-13}$ .

24. Determine the molar solubility of copper I thiocyanate ( $CuSCN$ ) whose  $K_{sp} = 1.64 \times 10^{-11}$ .

1.  $2 \times 10^{-3}$  M
- 2.  $4 \times 10^{-6}$  M Correct**
3.  $1 \times 10^{-2}$  M
4.  $2 \times 10^{-1}$  M

Explanation:  $K_{sp} = [Cu^+][SCN^-] = 1.64 \times 10^{-11}$   
 molar solubility =  $(1.64 \times 10^{-11})^{1/2} = 4 \times 10^{-6}$  M

25. Rank the following generic compounds from most to least soluble:

- CA  $K_{sp} = 10^{-8}$   
 $C_2A_3$   $K_{sp} = 10^{-20}$   
 $CA_3$   $K_{sp} = 10^{-16}$   
 $C_2A$   $K_{sp} = 10^{-12}$

1.  $CA_3 > C_2A_3 > CA > C_2A$
2.  $C_2A > CA_3 > C_2A_3 > CA$
3.  $CA > C_2A > CA_3 > C_2A_3$  **Correct**
4.  $C_2A_3 > CA > C_2A > CA_3$



Explanation: Molar solubility can be approximated by taking the nth root of the  $K_{sp}$  where n is the number of ions in the salt. Doing so results in approximate molar solubilities of  $10^{-4}$  for all of the salts. To resolve this difficulty, we must compare the number of cations and anions in each salt, with more total ions corresponding to lower molar solubility. Alternatively, one could actually calculate the molar solubility of each species.

26. Which equation below could be used to convert  $[H^+]$  into pOH?

1.  $pOH = -\log K_w + \log [H^+]$  **Correct**
2.  $pOH = \log(K_w/[H^+])$
3.  $pOH = pK_w + pH$
4. all of these equations could be used
5. none of these equations could be used

Explanation:  $pOH = pK_w - pH = -\log K_w - (-\log [H^+]) = -\log K_w + \log [H^+]$

27. Rank the following acids in the order of decreasing strength of their conjugate bases (strongest conjugate base to weakest conjugate base):

propionic acid ( $CH_3CH_2COOH$ )  $pK_a = 4.89$

hypochlorous acid ( $HClO$ )  $pK_a = 7.46$

formic acid ( $CHOOH$ )  $pK_a = 3.74$

nitrous acid ( $HNO_2$ )  $pK_a = 3.40$

1.  $CHOOH > HNO_2 > HClO > CH_3CH_2COOH$
2.  $CH_3CH_2COOH > CHOOH > HNO_2 > HClO$
3.  $HClO > CH_3CH_2COOH > CHOOH > HNO_2$  **Correct**
4.  $HNO_2 > HClO > CH_3CH_2COOH > CHOOH$

Explanation: Because the strength of an acid's conjugate base is inversely proportional to the strength of the acid, and the  $pK_a$  of an acid is also inversely proportional to strength of the acid, the strength of an acid's conjugate base is directly proportional to the  $pK_a$  of the acid. Therefore, ranking from highest  $pK_a$  to lowest  $pK_a$  will produce the correct ordering.

28. What would be the pH of a 0.05 M solution of  $Ca(OH)_2$  (Calcium Hydroxide) at room temperature?

1. 12.7
2. 13 **Correct**
3. 1.3
4. 1

Explanation: For a strong base,  $[OH^-] = C_b \cdot 2 = 0.05 \text{ M} \cdot 2 = 0.1 \text{ M}$

$pOH = -\log [OH^-] = -\log (0.1) = 1$

$pH = pK_w - pOH = 14 - 1 = 13$

29. What would be the pH of a 0.04 M solution of phenylammonium chloride ( $C_6H_5NH_3Cl$ ) at room temperature? (assume the  $K_b$  of phenylamine is  $4 \times 10^{-10}$ )

1. 11
2. 5.4
3. 8.6
4. 3 **Correct**
5. 7

Explanation: Phenylammonium chloride is an acidic salt composed of the conjugate acid of phenylamine and the spectator ion chloride.

$K_a = K_w / K_b = 10^{-14} / 4 \times 10^{-10} = 2.5 \times 10^{-5}$

For a weak acid solution,  $[H^+] = (K_a \cdot C_a)^{1/2} = (2.5 \times 10^{-5} \cdot 0.04)^{1/2} = (10^{-6})^{1/2} = 10^{-3}$

$pH = -\log [H^+] = -\log (10^{-3}) = 3$

30. If you had a 1 M solution of acetic acid ( $CH_3COOH$ ,  $K_a = 1.8 \times 10^{-5}$ ) and a 1 M solution of formic acid ( $CHOOH$ ,  $K_a = 1.8 \times 10^{-4}$ ), what would the difference in their pH be?

1. 3.2
2. 1.0

3. 0.5 **Correct**

4. 2.4

5. 2.9

Explanation: The only difference between the two solutions is their  $K_a$  values. These differ by a factor of 10, and so their  $[H^+]$  differ by a factor of  $10^{0.5}$ , and so their pH values differ by  $-\log 10^{0.5} = 0.5$