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(*Note: questions 1 to 14 are meant to be done WITHOUT calculators!)*

1.Which of the following is probably true for a solid solute with a highly endothermic heat of solution when dissolved in water?

1) The solid has a low lattice energy
2) As the solid dissolves, the temperature of the solution increases
3) The resulting solution is ideal.
4) The solid is more soluble at higher temperatures
5) The solid has a high energy of hydration

2. Two pure substances, A and B, each melt at 93.4°C. An unknown pure substance Q also melts at 93.4°C. Melting points are obtained on mixtures of Q + A, Q + B, and A + B, and in each case the melting point is below 93.4°C. Which of the following conclusions do these data support?

1) Q, A, and B are all different
2) Q,A, and B are all the same
3) Q is the same as A but different from B
4) Q is the same as B but different from A
5) A is the same as B but different from Q

3. The freezing point of p-dichlorobenzene is 53.1°C; its molal freezing point constant is 7.10°/m. A solution containing 66.7 grams of solute per kilogram of p-dichlorobenzene freezes at 50.2°C. What is the approximate molecular weight of the solute? 1) 370 2) 160 3) 62 4) 28 5) 14

4. An aqueous solution is 50. % by weight methanol, CH_3OH. (MM of methanol is 32, that of water is 18) What is the mole fraction of the methanol?

1) 0.16 2) 0.36 3) 0.50 4) 0.56 5) 0.64

5. Equal volumes of a 0.10M $Ca(NO_3)_2$ solution and 0.20M $NaNO_3$ solution are mixed. The molarity of the combined nitrate ion after mixing is

1) 0.05 M 2) 0.10 M 3) 0.15 M 4) 0.20 M 5) 0.30 M

6. At 20°C.,the vapor pressure of toluene is 22 torr and that of benzene is 75 torr. An ideal solution, equimolar in toluene and benzene is prepared. At 20° what is the mole fraction of benzene in the vapor in equilibrium with this solution?

1) 0.23 2) 0.29 3) 0.50 4) 0.77 5) 0.83

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7. A student wishes to prepare 2.00 liters of 0.100-molar KIO_3 .(molecular weight = 214) The proper procedure is to weigh out
   1) 42.8 grams of KIO_3 and add 2.00 kg of H_2O
   2) 42.8 g. of KIO_3 and add H_2O until the final homogeneous solution has a volume of 2.00 liters 3)21.4 g. of KIO_3 and add H_2O until the final homogeneous solution has a volume of
   2.00 liters.
   4) 42.8 grams of KIO_3 and add 2.00 liters of H_2O
   5) 21.4 grams of KIO_3 and add 2.00 liters of H_2O

8. Which of the following aqueous solutions has the highest boiling point?
   1) 0.10 M potassium sulfate, K_2SO_4
   2) 0.10 M hydrochloric acid, HCl 3) 0.10 M ammonium nitrate, NH_4NO_3.
   4) 0.10 M magnesium sulfate, $MgSO_4$ 5) 0.20 M sucrose, $C_{12}H_{22}O_{11}$

9. How much water must be added to 100. ml. of 3.0 M NaOH to produce a 0.50 M solution? 1) 500 ml 2) 600 ml. 3) 300 ml. 4) 6.0 liter 5) 5.0 liter

10. When the temperature is increased, the solubility of
    1) most solids and most gases increases 2) most solids and most gases decreases
    3) most solids increases, and most gases decreases
    4) most solids decreases, and most gases increases
    5) all substances whose dissolving process is exothermic increases.

11. Some solutions, such as an alcohol-water mixture, deviate from Raoult's Law in that the vapor pressure of the solution may attain a value which is higher than the vapor pressure of either pure component. This could be caused by
    1) a decrease in the volume of the solution
    2) evaporation of the solvent being impeded by the presence of solute particles on its surface, and vice versa
    3) The intermolecular attractions between the alcohol molecules being lowered by the presence of the water molecules, and vice versa
    4) the intermolecular attractions between alcohol molecules being raised by the presence of the water molecules, and vice versa
    5) the attractions between water and alcohol molecules far exceeding the attractions between the like molecules.

12.Henry's Law would best predict the change of solubility in water with changing temperature for the gas 1) SO_2 2) HCl 3) NH_3 4) N_2O_5 5) O_2

13-14. Liquids A and B form an ideal mixture. At 20^o the vapor pressure of pure A is 100 mm.; that of pure B is 50 mm. A solution contains 2.0 moles of A and 8.0 moles of B.

13. What is the partial pressure of vapor A in equilibrium with this solution?
1) 20 mm 2) 25 mm 3) 10 mm 4) 40 mm 5) 60 mm

14. What is the mole fraction of A in the vapor above the solution ?
1)0.20 2) 0.25 3) 0.33 4) 0.67 5) 0.80

Remaining questions were meant to be done WITH calculators where needed.

15. Which of the following solutions should have the highest boiling point? (tricky) 1) 5.8 g of NaCl in 100 g of water (mw of NaCl 58)
2) 92 g of C_2H_5OH in 100 g of water (mw of alcohol is 46)
3) 6.1 g of $KClO_3$ in 100 g of water. (mw of $KClO_3$ is 122)
4) 18.0 g of $C_6H_{12}O_6$ in 100 g of water. (mw of glucose is 180)
5) 3.0 g of NaOH in 100 g of water. (mw of NaOH is 40)

16. If 25.0 ml. of 0.200 M BrO_3^- is mixed with 30.0 ml. of 0.450 M Br^- solution that contains a large excess of H^+, the amount of Br_2 formed according to the equation above is
1) 5.00 X 10^{-3} mole 2) 8.10 X 10^{-3} mole 3) 1.35 X 10^{-3} mole 4) 0.015 mole
5) 0.162 mole

$$5\ Fe^{2+} + MnO_4^- + 8\ H^+ \rightarrow 5\ Fe^{3+} + Mn^{2+} + 4\ H_2O$$

17. In a titration experiment based on the equation above, 25.0 milliliters of an acidified Fe^{2+} solution requires 14.0 milliliters of standard 0.050-molar MnO_4^- solution to reach the equivalence point. The concentration of Fe^{2+} in the original solution is
1) 0.0010 M 2) 0.0056 M 3) 0.028 M 4) 0.090 M 5) 0.14 M

18. How many grams of silver nitrate,(m.w.=170) are required to prepare 25 ml. of a 0.15 M solution? 1) 6.4 g 2) 0.64g 3) 1.02 g 4) 10.2 g 5) 2.2 g

19. The vapor pressure of water at 50^o is 92.5 mm of Hg. What is the vapor pressure of a solution containing 180.0 g of glucose, (mw=180) dissolved in 180 g of water?
1) 84.1 mm 2) 83.2 mm 3) 46.2 mm 4) 103 mm 5) 9.25 mm

20. Assuming that the solution is ideal, what is the boiling point of an aqueous NaCl solution which freezes at -0.41^oC? (The freezing point constant is 1.86^o; the boiling point constant is 0.52^o) 1) 100.15^o 2) 100.22^o 3) 100.06^o 4) 99.78^o 5) 100.11^o

Part II. Answer question I, and any three of the others. Extra credit if you do all of them. Note that question I is worth 30 points, while the other essays are 12 each. Your total score will then be multiplied by 1.6 to obtain an essay grade.

I. A comparison of the theories of Arrhenius, Brönsted, and Lewis shows a progressive generalization of the acid base concept.
A. Outline the essential ideas of each theory. (9 points)
B. Below are five chemical reactions. They are all acid base reactions according to at least one of the theories described in part A. For each reaction indicate which theories apply, and which do not. Briefly explain each answer. (15 pts.)

1. $HCl + NaOH \rightarrow NaCl + H_2O$

2. $SO_3 + CaO \rightarrow CaSO_4$

3. $BCl_3 + NH_3 \rightarrow BCl_3NH_3$

4. $NH_3 + HNO_3 \rightarrow NH_4NO_3$

5. $CH_3NH_2 + H_2O \rightarrow CH_3NH_3^+ + OH^-$

C. For the reaction $Cu^{2+} + 4\ H_2O \rightarrow Cu(H_2O)_4^{2+}$, identify the Lewis acid and the Lewis base, and explain your selections. (6 pts.)

Remaining essays are 12 points each.

II. In each of the following cases, a slight excess of dilute base is added to 0.05 M solution of the acid. The resulting heats of neutralization per mole of acid reacting are indicated for each acid base reaction.

	Heat of neutralization
a) HCl + NaOH	13.7 kcal.
b) HNO_3 + KOH	13.7 kcal.
c) HCl + NH_3	12.6 kcal.
d) CH_3COOH + KOH	13.4 kcal.
e) $HClO_4$ + KOH	13.7 kcal.

A. Account for the fact that the heats are the same in a, b and e

B. Account for the fact that they are different in c and d.

III. A 100 ml. solution of 0.40 M NaOH is mixed with 50.0 ml of 0.20 M H_2SO_4. Calculate the molarity of Na^+, SO_4^{2-}, and OH^- in the resulting solution.

IV. A solution containing 12.0 g of solute dissolved in 800 g of water freezes at -0.607^o C. What is the molecular weight of the solute? The solution boils at a temperature of 90^o. What conclusion can you draw about the nature of the solute?

V. Concentrated solutions of NH_3 in water are 28 % NH_3 by weight, and have a density of 0.90 g/ ml. Find

a) The molarity of NH_3 in the solution b) the molality of NH_3 in the solution c) the mole fraction of WATER in the solution. d) the freezing point of the solution, if the ionization of the NH_3 is negligible.