CHM 102
Exam I

1. Concentrated hydrochloric acid is a solution of 37.2% HCl by mass. The density of concentrated HCl is 1.19 g / mL.

mw (HCl): 36.46 g/mol

a) How many moles of HCl are in 1.00 L of concentrated HCl?

$$1.00 L\ HCl \cdot \frac{1000 mL}{1 L} \cdot \frac{1.19 g\ soln}{1 mL\ soln} \cdot \frac{37.2 g\ HCl}{100 g\ soln} \cdot \frac{1 mol\ HCl}{36.46 g\ HCl} = 12.2 mol\ HCl$$

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b) What is the molarity of concentrated HCl?

$$\frac{12.2 mol\ HCl}{1 L\ HCl} = 12.2 M\ HCl$$

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c) What volume of concentrated HCl is necessary to prepare 2.5 L of 6.0 M HCl?

$$M_1 V_1 = M_2 V_2$$

$$6.0 M \cdot 2.5 L = 12.2 M\ V_2$$

$$V_2 = \frac{6.0 \cdot 2.5}{12.2} = 1.23 L\ conc.\ HCl$$

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2. Nitrogen melts at -210 °C and boils at -196 °C. The enthalpy of vaporization of liquid N_2 is $\Delta H_v = 5.58$ kJ / mol.

a) Suppose a freshly prepared sample of nitrogen at -205 °C is allowed to warm to room temperature, 25 °C. Plot the temperature of the nitrogen versus time and label any appropriate phase changes on the plot with their corresponding temperatures.

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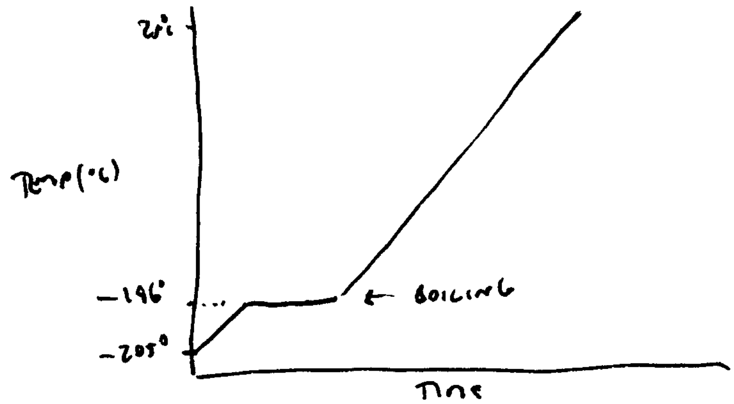

b) Suppose that 500 g of $N_2(l)$ at -196 °C is poured into a well-insulated vessel containing 1.50 L of water at 25 °C. How much energy does the nitrogen absorb as it boils off? Assume that once the nitrogen vaporizes, it leaves the vessel without absorbing additional energy.

$q = n \cdot \Delta H_v$

$n = 500\,g\,N_2 \cdot \frac{1\,mol\,N_2}{28.01\,g\,N_2} = 17.85\,mol\,N_2$

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$q = 17.85\,mol \cdot \frac{5.58\,kJ}{mol} = \boxed{99.6\,kJ}$

c) The density of water is 1.00 g / mL and its heat capacity is 4.184 J / g · °C. What is the final temperature of the water in the vessel once all of the nitrogen has boiled away?

$q = m \cdot C \cdot \Delta T$

$m = 1.5\,L \cdot \frac{1000\,g}{1\,L} = 1500\,g\,H_2O$

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$99.6 \times 10^3\,J = 1500\,g \cdot 4.184\,\frac{J}{g \cdot °C} \cdot \Delta T$

$\Delta T = 15.87\,°C$ so $T = 25 - 15.87 = \boxed{9.13\,°C}$

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3. In candy making, a given amount of sugar is dissolved in an excess of liquids, and the water is boiled away until the solution reaches its desired concentration. The sugar syrup is then worked into candy.

a) The best fudge is made when the sugar syrup is cooked until its boiling point is 234 °F (112 °C). For water, the ebullioscopic constant $K_b = 0.512$ kg · °C / mol. What is the molality of the sugar solution in the optimal fudge syrup?

$$\Delta T_b = m \cdot K_b$$

$$\Delta T_b = 112 - 100 = 12 = m \cdot 0.512 \frac{kg \cdot °C}{mol}$$

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$$m = \boxed{23.4 \frac{mol}{kg} \text{ sucrose}}$$

b) How many moles of sugar ($C_{12}H_{22}O_{11}$) are dissolved in 1.00 kg of water at this temperature?

$$\frac{23.4 \text{ mol } C_{12}H_{22}O_{11}}{kg} \cdot 1 \text{ kg } H_2O = \boxed{23.4 \text{ mol } C_{12}H_{22}O_{11}}$$

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c) What is the percentage by mass of sucrose in this solution?

$$23.4 \text{ mol } C_{12}H_{22}O_{11} \cdot \frac{342.30 \text{ g } C_{12}H_{22}O_{11}}{1 \text{ mol } C_{12}H_{22}O_{11}} = 8{,}009.7 \text{ g } C_{12}H_{22}O_{11}$$

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$$\% \text{ mass} = \frac{8.010 \text{ kg } C_{12}H_{22}O_{11}}{8.010 \text{ kg } C_{12}H_{22}O_{11} + 1.00 \text{ kg } H_2O} = \boxed{88.9\% \text{ by mass}}$$

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4. Potassium permanganate is a common oxidizing agent used in many applications in the laboratory. One application of permanganate is in the determination of the sulfite content of aqueous solutions. In this reaction, permanganate reacts with bisulfite in the presence of acid to form manganese (II), bisulfate, and water, as shown below:

$$6\ H^+(aq) + 2\ MnO_4^-(aq) + 5\ HSO_3^-(aq) \rightarrow 2\ Mn^{2+}(aq) + 5\ HSO_4^-(aq) + 3\ H_2O(l)$$

a) Suppose you first need to prepare 1.00 L of a stock MnO_4^- solution that is 1.00 M. What mass of potassium permanganate ($KMnO_4$) is required to make this solution?

$M_m(KMnO_4) = 158.03\ g/mol$

$1.00\ L\ KMnO_4 \cdot \frac{1\ mol\ KMnO_4}{1\ L\ KMnO_4} \cdot \frac{158.03\ g\ KMnO_4}{1\ mol\ KMnO_4} = \boxed{158\ g\ KMnO_4}$

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b) This solution is too concentrated to use directly, so you must dilute it down to 1.00×10^{-3} M. What volume of the 1.00×10^{-3} M permanganate solution can you make with 1.00 L of the 1.00 M permanganate?

$M_1 V_1 = M_2 V_2$

$1.00 \times 10^{-3}\ V_1 = 1.00\ M \cdot 1.00\ L$

$V_1 = \frac{1 \cdot 1}{1 \times 10^{-3}} = \boxed{1000\ L\ \ 1.00 \times 10^{-3}\ M\ KMnO_4}$

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c) Suppose a 25.00 mL sample of HSO_3^- reacts completely with 17.41 mL of the 1.00×10^{-3} M MnO_4^-. What is the molarity of the HSO_3^- solution?

$0.01741\ L\ MnO_4^- \cdot \frac{1.00 \times 10^{-3}\ mol\ MnO_4^-}{1\ L\ MnO_4^-} \cdot \frac{5\ mol\ HSO_3^-}{2\ mol\ MnO_4^-} \cdot \frac{1}{0.02500\ L\ HSO_3^-} =$

$\boxed{1.741 \times 10^{-3}\ M\ HSO_3^-}$

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5. Explain the following phenomena:

a)

Structure	Viscosity (mN · s / m^2)	Surface Tension (dyne / cm)
$CH_3CH_2CH_2CH_2Cl$	0.469	24.29
$CH_3CH_2CH_2CH_2OH$	2.948	25.83

$CH_3CH_2CH_2CH_2OH$ CAN HYDROGEN BOND WHILE $CH_3CH_2CH_2CH_2Cl$ HAS ONLY WEAKER DIPOLE-DIPOLE FORCES. THUS, THE STRONGER INTERMOLECULAR INTERACTION IN $CH_3CH_2CH_2CH_2OH$ LEAD TO HIGHER VISCOSITY AND STRONGER SURFACE TENSION.

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b) The temperature of a liquid cannot exceed its boiling point.

WHEN A LIQUID REACHES ITS BOILING POINT, ALL ADDITIONAL ENERGY ADDED GOES TO VAPORIZING THE LIQUID. ONCE ALL OF THE LIQUID IS VAPORIZED, ITS TEMPERATURE RISES AGAIN, BUT THE SUBSTANCE IS NOW ENTIRELY IN THE GAS PHASE.

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c) Water at 100 °C is a less efficient carrier of thermal energy than steam at 100 °C.

WHEN WATER COOLS, IT CAN ONLY RELEASE THE ENERGY AS GIVEN BY ITS HEAT CAPACITY. ON THE OTHER HAND, STEAM WILL LIBERATE ITS HEAT OF VAPORIZATION IN ADDITION TO THE ENERGY OF THE LIQUID AS IT COOLS.

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For the remaining questions, circle the letter that corresponds to the best answer.

6. A solution is prepared by adding a sufficient amount of solid solute to the solvent that some solid remains after the solution has been heated and allowed to cool to room temperature. This solution is then carefully decanted (poured off) from the solid. This solution would be considered:

- (A) dilute
- (B) unsaturated
- **(C)** saturated
- (D) supersaturated
- (E) stoichiometric

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7. Acetic acid (CH_3CO_2H) melts at 16.6 °C and boils at 117.9 °C. Consider the following processes:

I. Heat 100 g of acetic acid from 20 to 30 °C
II. Heat 100 g of acetic acid from 100 to 110 °C

Which of the following is *true*?

- (A) The amount of energy required for **I** is less than the amount of energy required for **II** because acetic acid is at a lower temperature in **I**.
- (B) The amount of energy required for **I** is greater than the amount of energy required for **II** because the acetic acid is closer to its boiling point in **II**.
- (C) The amount of energy required for **I** will be greater than the amount of energy required for **II** because the solid to liquid phase change requires energy.
- **(D)** The amounts of energy required for **I** and **II** are equal.
- (E) The relative energies required for these processes cannot be compared without additional information.

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8. Phenol (C_6H_5OH) melts at 40.5 °C and boils at 181.7 °C. A solution of 166 g of KI in 1 kg of phenol melts at 25.7 °C.

1 mol KI
2 mol ions

What is the melting point of a solution of 166 g of $C_{13}H_{10}$ (fluorene, not to be confused with the halogen fluorine) in 1 kg of phenol?

1 mol $C_{13}H_{10}$

- (A) 47.9 °C
- (B) 40.5 °C
- **(C)** 33.1 °C
- (D) 25.7 °C
- (E) 18.3 °C

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$\Delta T_m = 40.5 - 25.7 = 14.8°C$

$\Delta T_m = m \cdot K_f$

$14.8 = \frac{2\ mol\ ions}{1\ kg} \cdot K_f$

$K_f = 7.4\ \frac{kg\,°C}{mol}$

$\Delta T_m = \frac{1\ mol\ C_{13}H_{10}}{1\ kg} \cdot 7.4\ \frac{kg\,°C}{mol}$

$= 7.4°C$

$T_m = 40.5 - 7.4 = 33.1°C$

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9. Which substance has the highest melting point?

(A) CH_4
(B) CO_2
(C) CH_3OH
(D) CH_3F
(E) not enough information

10. A 100 g sample of $CHCl_3$ requires 26.3 kJ of energy to boil. What is the heat of vaporization?

(A) 2.63 kJ / mol
(B) 3.80 kJ / mol
(C) 4.54 kJ / mol
(D) 22.0 kJ / mol
(E) 31.4 kJ / mol

11. Which of the following compounds can engage in hydrogen bonding?

I. BH_3
II. H_2
III. NH_3
IV. NaH
V. HF

(A) **II** only
(B) **III** only
(C) **I** and **III**
(D) **III** and **V**
(E) **I**, **II**, and **IV**

12. An insect's ability to walk on water is an example of:

(A) viscosity

(C) solubility
(D) stoichiometry
(E) surface tension

13. Suppose sufficient thermal energy has been added to a solid substance to reach its melting point. Which of the following statements describe what happens to additional energy added?

I. ✗ Additional energy raises the temperature of the solid, which makes it melt faster.
II. ✓ Additional energy disrupts the intermolecular forces holding the solid together
III. ✗ Additional energy increases the melting point of a substance, which is why it must be continually heated in order to completely melt.
IV. ✓ Additional energy maintains melting, since the process is endothermic and requires that energy be continually added.
V. ✗ Additional energy increases the temperature of the liquid.

(A) **I** only
(B) 2 **II** only
(C) **I** and **III**
(D) **II** and **IV**
(E) **III** and **V**

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14. Which of the following is a correct ranking of compounds in order of *increasing* melting point?

(A) $HF < NaF < CH_3F < F_2$
(B) $NaF < F_2 < CH_3F < HF$
(C) $NaF < HF < F_2 < CH_3F$
(D) $F_2 < CH_3F < NaF < HF$
(E) $F_2 < CH_3F < HF < NaF$

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15. Which of the following 1 m solutions has the highest melting point?

(A) $NaCl$ 2
(B) $CaCl_2$ 3
(C) $C_6H_{12}O_6$ 1
(D) Na_2S 3
(E) K_3PO_4 4

Highest mp = Lowest conc.

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