START 8:00

END 10:00

CHM 102
Exam I

1. Hydrazine (N_2H_4) is a reagent that is used in many applications, from polymers to rocket fuel. Pure hydrazine melts at 2.0 °C, boils at 113.5 °C, and has a density of 1.011 g / mL.

a) How many moles of hydrazine are present in one liter of pure N_2H_4? MW: 32.045 g/mol

$$\frac{1.011\ g\ N_2H_4}{1\ mL\ N_2H_4} \cdot \frac{1000\ mL}{L} \cdot \frac{1\ mol\ N_2H_4}{32.045\ g\ N_2H_4} \cdot 1L = \boxed{31.55\ mol\ N_2H_4}$$

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b) What is the molarity of pure hydrazine?

$$\frac{31.55\ mol\ N_2H_4}{1L\ N_2H_4} = \boxed{31.55\ \underline{M}\ N_2H_4}$$

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c) A 1.00 <u>M</u> aqueous solution of hydrazine is desired for routine lab work. What volume of pure hydrazine must be diluted to 500 mL to produce this solution?

$$M_1V_1 = M_2V_2$$

$$1.00\ \underline{M} \cdot 0.5L = 31.55\ \underline{M} \cdot V_2$$

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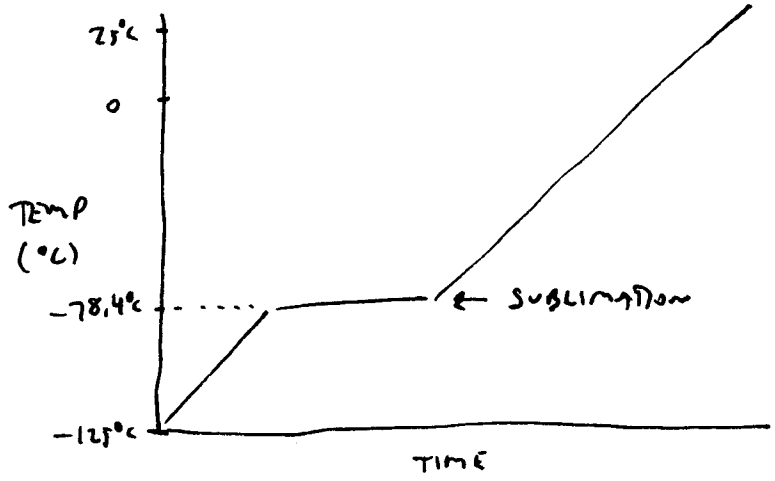
$$V_2 = \frac{1.00 \cdot 0.5}{31.55} = 0.0158\ L\ N_2H_4$$

$$= \boxed{15.8\ mL\ N_2H_4}$$

2. CO_2 is relatively uncommon in that it sublimes at atmospheric pressure (at -78.4 °C). Solid CO_2 has the common name "dry ice" due to this lack of a liquid phase under normal conditions. Dry ice sometimes finds use in theatrical applications where it is placed in a container of warm water and creates a billowing fog that creeps along the ground. This fog is not the CO_2 gas, but is actually water vapor condensed out of the air when it contacts the very cold carbon dioxide.

a) Suppose that you have a sample of dry ice, freshly prepared, at a temperature of -125 °C. You allow it to sublime and warm to room temperature (25 °C). Sketch a plot of the temperature of the carbon dioxide versus time and label the sublimation point on the plot.



b) Suppose that 1.00 kg of dry ice at -78.4 °C completely sublimes. How much energy does the carbon dioxide absorb as it sublimes? For CO_2, ΔH_s = 25.2 kJ / mol.

$q = n \cdot \Delta H_s$ $\quad n = 1000\,g\,CO_2 \cdot \frac{1\,mol}{44.01\,g} CO_2 = 22.72\,mol\,CO_2$

$q = 22.72\,mol \cdot \frac{25.2\,kJ}{mol} = \boxed{572.6\,kJ}$

c) Suppose this process takes place in a container filled with 10.0 L of water at a temperature of 40.0 °C. What is the final temperature of the water? Water has a density of 1.00 g / mL and a heat capacity of C = 75.3 J / mol · °C.

$q = n \cdot C \cdot \Delta T$ $\quad n = 10000\,mL \cdot \frac{1.00\,g}{mL} \cdot \frac{mol}{18.02\,g} = 554.94\,mol\,H_2O$

$\frac{1000\,J}{kJ} \cdot 572.6\,kJ = 554.94\,mol \cdot \frac{75.3\,J}{mol \cdot °C} \cdot \Delta T$

$\Delta T = 13.7°C$

$T = 40.0°C - 13.7°C = \boxed{26.3°C}$

3. Potassium dichromate ($K_2Cr_2O_7$) is a reagent used in many analytical reactions because it is stable, easy to obtain in high purity, and has a high molecular weight.

a) Suppose you wanted to prepare 2.00 L of a solution that is 0.100 M potassium dichromate. What mass of $K_2Cr_2O_7$ must you use? mw = 294.18 g/mol

$$2.00\,L\ K_2Cr_2O_7 \cdot \frac{0.100\ mol\ K_2Cr_2O_7}{1\ L\ K_2Cr_2O_7} \cdot \frac{294.18\ g\ K_2Cr_2O_7}{1\ mol\ K_2Cr_2O_7} = \boxed{58.84\ g\ K_2Cr_2O_7}$$

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b) This dichromate solution can then be used to determine the amount of iron (II) in ore samples by the following net ionic reaction:

$$14\ H^+(aq) + Cr_2O_7^{2-}(aq) + 6\ Fe^{2+}(aq) \rightarrow 7\ H_2O(l) + 2\ Cr^{3+}(aq) + 6\ Fe^{3+}(aq)$$

If a 50.00 mL sample of $Fe^{2+}(aq)$ of unknown concentration reacts completely with 34.73 mL of standard 0.100 M dichromate solution, what is the concentration of iron (II) in the unknown solution?

vol $Cr_2O_7^{2-}$ → mol $Cr_2O_7^{2-}$ → mol Fe^{2+} → conc. Fe^{2+}

$$0.03473\ L\ Cr_2O_7^{2-} \cdot \frac{0.100\ mol\ Cr_2O_7^{2-}}{1\ L\ Cr_2O_7^{2-}} \cdot \frac{6\ mol\ Fe^{2+}}{1\ mol\ Cr_2O_7^{2-}} \cdot \frac{1}{0.05000\ L\ Fe^{2+}}$$

$$= \boxed{0.4168\ M\ Fe^{2+}}$$

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c) Suppose this 50.00 mL sample of iron (II) came from the digestion of a 15.21 g sample of iron ore. What is the percentage of iron (II) by mass in the ore?

vol Fe^{2+} → mol Fe^{2+} → mass Fe^{2+} → mass %

$$0.05000\ L\ Fe^{2+} \cdot \frac{0.4168\ mol\ Fe^{2+}}{1\ L\ Fe^{2+}} \cdot \frac{55.845\ g\ Fe^{2+}}{1\ mol\ Fe^{2+}} = 1.169\ g\ Fe^{2+}$$

$$\frac{1.169\ g\ Fe}{15.21\ g} \times 100\% = \boxed{7.685\%\ Fe^{2+}\ by\ mass}$$

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4. Explain the following phenomena:

a) Vodka (which is a 40% solution of aqueous C_2H_5OH) remains a liquid even if put in the freezer.

SOLUTION FREEZING POINTS ARE LOWER THAN PURE SOLVENT FREEZING POINT BECAUSE THE SOLUTE INTERFERES WITH SOLVENT CRYSTALLIZATION.

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b) Methane (CH_4) boils at -161.45 °C while ammonia (NH_3) boils at -33.34 °C.

AMMONIA HAS A HIGHER BOILING POINT THAN METHANE BECAUSE IT CAN HYDROGEN BOND WHILE METHANE ONLY HAS DISPERSION FORCES. AMMONIA'S STRONGER INTERMOLECULAR FORCES GIVE IT A HIGHER BOILING POINT.

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c) Steam at 100 °C causes much worse burns than liquid water at 100 °C.

LIQUID WATER AT 100°C ONLY RELEASES ENERGY AS IT COOLS. STEAM MUST FIRST CONDENSE, RELEASING THE HEAT OF VAPORIZATION, BEFORE IT CAN RELEASE ENERGY TO LOWER ITS TEMPERATURE.

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5. We normally do not consider the concentration of water in aqueous solutions, but it is important in some cases. The density of pure water is 1.00 g / mL.

a) What is the molarity of pure water?

$$\frac{1.00\ g\ H_2O}{1\ mL\ H_2O} \cdot \frac{1000\ mL}{1\ L} \cdot \frac{1\ mol\ H_2O}{18.02\ g\ H_2O} = \boxed{55.49\ M\ H_2O}$$

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b) Seawater is about 3.4% dissolved salt by mass. If the density of seawater is 1.025 g / mL, what mass of *water* is in 1.00 L of seawater?

$$1.00\ L\ \text{SEAWATER} \cdot \frac{1025\ g\ \text{SEAWATER}}{1\ L\ \text{SEAWATER}} \cdot \frac{3.4\ g\ \text{SALT}}{100\ g\ \text{SEAWATER}} = 34.85\ g\ \text{SALT}$$

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$$\text{MASS } H_2O = 1025\ g - 34.85\ g = \boxed{990.15\ g\ H_2O}$$

c) What is the molarity of water in seawater?

$$\frac{990.15\ g\ H_2O}{1\ L\ H_2O} \cdot \frac{1\ mol\ H_2O}{18.02\ g\ H_2O} = \boxed{54.95\ M\ H_2O}$$

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d) Why does drinking seawater cause dehydration, despite the fact that seawater is mostly water?

DUE TO ITS HIGH SALT CONTENT, THE CONCENTRATION OF H_2O IN SEAWATER IS LOWER THAN THE CONCENTRATION OF WATER IN BODY TISSUES. THUS, WATER WILL UNDERGO OSMOSIS AND TRAVEL FROM BODY TISSUES INTO THE SEAWATER.

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For the remaining questions, circle the letter corresponding to the best answer.

6. A solution is prepared by adding a sufficient amount of a solid solute so that after heating the solution and allowing it to cool there is a visible amount of solid left on the bottom of the beaker. This solution would be considered:

(A) unsaturated
(B) saturated
(C) supersaturated
(D) dilute
(E) polar

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7. Silver chloride (AgCl) is essentially insoluble in water while sodium chloride (NaCl) is freely soluble. Which of the following statements are *true*?

I. ✗ AgCl is a nonpolar molecular solid so it does not dissolve in the highly polar water.
II. ✓ The interactions within AgCl are stronger than the interactions of silver metal and chlorine gas with water.
III. ✓ The interactions of silver ions and chloride ions with water are weaker than the interactions between silver ions and chloride ions.
IV. ✗ The interactions of sodium ions and chloride ions with water are weaker than the interactions between sodium ions and chloride ions.
V. ✓ The interactions of sodium ions and chloride ions with water are stronger than the interactions between sodium ions and chloride ions.

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

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8. How many moles of nitrogen (N_2) can be produced by the complete decomposition of 2.50 moles of TNT, $C_7H_5N_3O_6$?

$C_7H_5N_3O_6 \rightarrow \frac{3}{2} N_2 + \ldots$

$2.50 \text{ mol TNT} \cdot \frac{\frac{3}{2} \text{ mol } N_2}{1 \text{ mol TNT}} = 3.75 \text{ mol } N_2$

(A) 1.25 moles
(B) 2.50 moles
(C) 3.00 moles
(D) 3.75 moles
(E) 7.50 moles

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9. Which substance has the highest melting point?

(A) C_2H_5F
(B) C_2H_6
(C) C_2F_6
5 (D) C_2H_5OH
(E) not enough information

10. A 20.0 g sample of phenol (C_6H_5OH, MW = 94.11 g / mol) requires 2.44 kJ of energy to melt. The heat of fusion of phenol is:

$20_g\ C_6H_5OH \cdot \frac{1\text{ mol } C_6H_5OH}{94.11_g\ C_6H_5OH} \cdot 0.213\text{ mol } C_6H_5OH$

(A) 0.122 kJ / mol
(B) 0.213 kJ / mol
(C) 2.44 kJ / mol
5 (D) 11.5 kJ / mol
(E) 48.8 kJ / mol

$\frac{2.44\text{ kJ}}{0.213\text{ mol}} = 11.5\text{ kJ/mol}$

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

(A) solubility
(B) dispersion forces
(C) viscosity
5 (D) surface tension
(E) colligative properties

12. When sufficient thermal energy is added to reach the boiling point of a substance, what happens to any additional energy added?

(A) ✗ Additional energy raises the temperature of the liquid which in turn increases the rate of boiling.
(B) ✓ Additional energy maintains boiling, since the process is endothermic and thus requires that energy be continually added.
5 (C) ✗ Additional energy increases the intermolecular interactions between liquid molecules, which increases the volatility of the substance.
(D) ✗ Additional energy will raise the temperature of the vapor and thus make the substance more volatile.
(E) ✗ Additional energy raises the vapor pressure and increases the boiling point, which is why the substance must be continually heated in order to boil.

13. Benzene (C_6H_6) melts at 5.5 °C and boils at 80.1 °C. Consider the following processes:

I. Heat 100 g of benzene from 10 °C to 15 °C
II. Heat 100 g of benzene from 70 °C to 75 °C

Which of the following is *true*?

(A) ✓ The amounts of energy required for **I** and **II** are equal.
(B) ✗ The amount of energy required for **I** is less than the amount of energy required for **II** because benzene is at a lower temperature in **I**.
(C) ✗ The amount of energy required for **I** is greater than the amount of energy required for **II** because benzene is nearly boiling in **II**.
(D) ✗ The amount of energy required for **I** will be greater than the amount of energy required for **II** because it takes energy to melt a solid.
(E) ✗ The amount of energy required for these processes cannot be compared without additional information.

14. Dimethylsulfoxide, $(CH_3)_2SO$, is a solvent commonly used in organic chemistry that melts at 18.5 °C and boils at 189 °C. A solution of 119 g of KBr in 1 kg of DMSO melts at 9.1 °C.

What is the melting point of a solution of 128 g of naphthalene ($C_{10}H_8$) in 1 kg of DMSO?

(A) 23.2 °C
(B) 18.5 °C
(C) 13.8 °C
(D) 9.1 °C
(E) 4.4 °C

mw (KBr) = 119 g/mol 1 m soln :: 2 m particles
mw ($C_{10}H_8$) = 128 g/mol 1 m soln

$\Delta T = 2 \cdot K_f$
$18.5 - 9.1 = 2 \cdot K_f$
$K_f = 4.7$

$\Delta T = 1 \cdot 4.7 = 4.7\,^\circ C$
$T = 18.5 - 4.7\,^\circ C = \boxed{13.8\,^\circ C}$

15. Which of the following substances exhibit hydrogen bonding?

I. ✗ CH_4
II. ✓ H_2O
III. ✗ CaH_2
IV. ✓ HF
V. ✗ H_2

(A) **II** only
(B) **V** only
(C) **II** and **III**
(D) **II** and **IV**
(E) all of the above