Name: Answer Key Lab Section: _____

Exam #2

Mark your answers on this exam, showing all work (including units) where appropriate. If you have a question about one of the exam items, write it on the exam and I will take it into consideration when grading your exam. The Periodic Table is on the last page. Questions 1-19 are worth 3.5 pts., questions 20-25 are worth 5.5 pts.

$K_{fp}(H_2O)$= -1.86°C/m **$K_{bp}(H_2O)$= 0.51°C/m** **1atm=760mmHg** **R=0.0821 L·atm/K·mol**

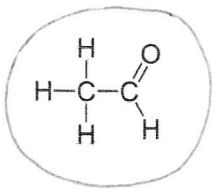
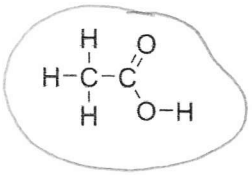
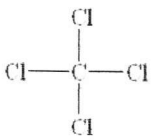
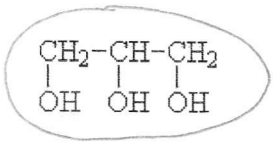
1) Which of the following intermolecular forces is the strongest?
   a) Induced dipole
   b) Dipole
   c) Hydrogen bond
   d) All intermolecular forces are the same strength

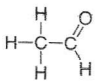
2) Which of the following statements are true?
   a) As intermolecular force strength increases, ΔH_{vap} increases.
   b) As intermolecular force strength increases, boiling point decreases.
   c) A compound with weaker intermolecular forces will have a lower vapor pressure.
   d) A compound with stronger intermolecular forces will have a lower vapor pressure.

3) What happens to the boiling point of water when sugar, a nonionic solute, is dissolved in it?
   a) The boiling point increases.
   b) The boiling point decreases.
   c) The boiling point stays the same.

4) Which of the following compounds will have the highest boiling point?
   a) CH_3CH_3
   b) $CH_3CH_2CH_2CH_3$
   c) $CH_3CH_2CH_2CH_2CH_2CH_2CH_3$
   d) $CH_3(CH_2)_{10}CH_3$ ← All of these are hydrocarbons, so the largest one will have the strongest induced dipole forces and hence the highest boiling point.
   e) All hydrocarbons have the same boiling point

5) Circle the compounds that are very water soluble:

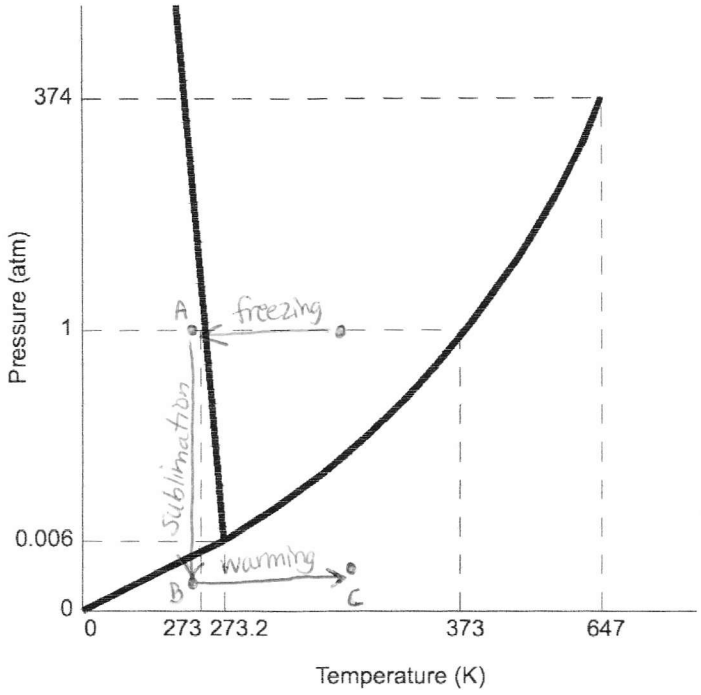





6) Can an acetaldehyde molecule form a hydrogen bond with another acetaldehyde molecule? The Lewis structure for acetaldehyde is: 

YES NO

7) A hydrophobic molecule
   a) can form hydrogen bonds with water.
   b) is nonpolar.
   c) never contains O or N atoms.
   d) is very soluble in water.

The following figure is the phase diagram for water. Use it for questions 8 and 9.



8) The atmosphere on the planet Mars is much thinner than Earth's, with an average atmospheric pressure of 0.006 atm. The average surface temperature on Mars is 210 K (-63°C). Under these conditions, in which phase can water NOT be found?
   a) Solid
   b) Liquid
   c) Gas

9) Freeze-drying can remove 97% or more of the water in food. This process involves three steps:
   a) The food is first frozen at 0°C under normal pressure,
   b) Then the pressure is reduced below 0.006 atmospheres.
   c) Finally, the food is slowly warmed to a temperature above the freezing point of water while a vacuum is applied.

   Mark the above phase diagram to indicate the three points described above (use A, B, and C to label each point appropriately). Connect the points with arrows to show the transition between A→B and B→C and label each transition (e.g., boiling, freezing, condensation, etc.).

10) What is the primary reason that oil and water do not mix?

a) If they did, many strong hydrogen bonds would need to be broken
b) In order to do so, the water would need to first be vaporized, which requires too much energy
c) If they did, the entropy of water would decrease markedly
d) The intermolecular forces between the nonpolar molecules are too strong

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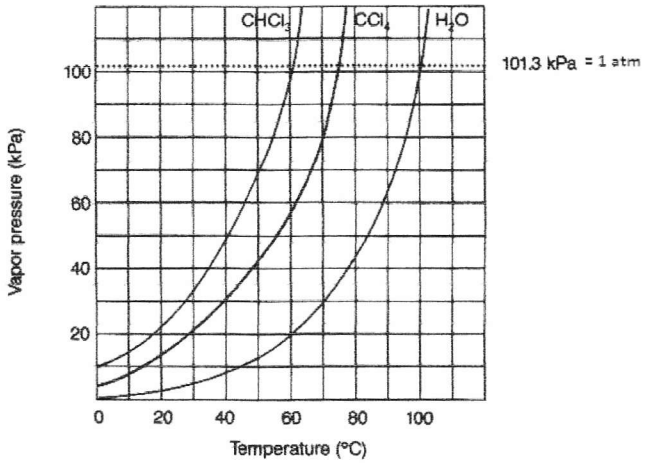
Consider the following vapor pressure graph to answer the following questions (Include the appropriate units, if necessary for full credit):



11) Which substance has the strongest IMF? H_2O

12) What is the vapor pressure of $CHCl_3$ at 40°C? 50 kPa

13) What is the boiling point of water when the external pressure is 30 kPa? 70°C

14) What is the normal boiling point of CCl_4? 75°C

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15) A metastable state of matter is one that is:

a) Very reactive
b) Thermodynamically stable but kinetically unstable
c) Kinetically stable but thermodynamically unstable
d) Stable in terms of enthalpy but not entropy

16) When potassium hydroxide (KOH) is added to water, the solution gets colder as the salt dissolves. How would the solubility of KOH change if we applied heat?

→ endothermic

a) The solubililty would decrease.
b) The solubility would increase.
c) The solubility would remain the same.
d) More information is needed to answer this question.

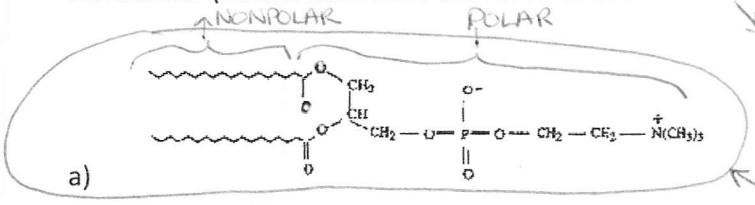
$KOH + heat + water \rightarrow KOH(aq)$

$\Delta H = +$

24.5

17) Oxygen exchange in the lungs takes place across the membranes of small balloon-like structures called alveoli. The alveoli are coated with a surfactant which reduces surface tension and allows easier inflation of the alveoli. The incomplete formation of this surfactant makes respiration difficult for premature infants. Which of the following molecules could be a component of the pulmonary **surfactant**? (Hint: it must have the features of a surfactant.)

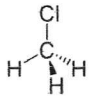
a)



surfactants have both a nonpolar and a polar portion

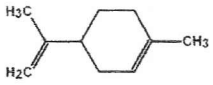
This is phosphatidylcholine. It is one of the major components of pulmonary surfactant.

b)

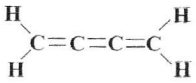


All polar

c)

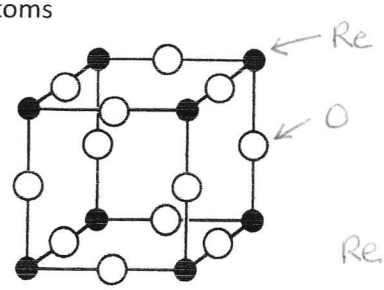


d)



All nonpolar

18) What is the formula for the compound which has this unit cell? The black circles represent Re atoms and the white circles represent O atoms



a) ReO
b) Re_3O
c) ReO_3
d) Re_8O_{12}
e) Re_2O_3

ReO_3

Re = 8 atoms on corners
$\frac{1}{8}$ of a corner atom is in the cell
∴ there is 1 Re atom in the cell

O = 12 atoms on edges
$\frac{1}{4}$ of an edge atom is in the cell
∴ there are 3 O atoms in the cell

19) How would the carbonation of an open can of soda be affected on top of Mt. Washington, where atmospheric pressure is 0.80 atm?

a) The soda would take longer to go flat.
b) The soda would go flat faster.
c) The soda would never go flat.

Increased pressure increases gas solubility.
Decreased pressure decreases gas solubility.

For this cell type, there are 4 atoms/cell and the radius of the atom = 0.35355 × edge length (from Table 12.2)

20) Calcium metal crystallizes in a face centered cubic unit cell. The density of the solid is 1.54 g/cm^3. What is the radius of the calcium atom?

We will use the density to get the volume of the unit cell, then get the edge from the volume, and finally the radius from the edge length.

$$\text{Volume} = \frac{\text{mass}}{\text{density}} = \frac{\left(\frac{40.078\text{ g}}{\text{mole}}\right)\left(\frac{1\text{ mole}}{6.022\times10^{23}\text{ atoms}}\right)\left(\frac{4\text{ atoms}}{\text{cell}}\right)}{(1.54\text{ g/cm}^3)} = 1.7286\times10^{-22}\text{ cm}^3/\text{cell}$$

$$\text{Edge length} = \sqrt[3]{\text{Volume}} = \left(1.7286\times10^{-22}\frac{\text{cm}^3}{\text{cell}}\right)^{\frac{1}{3}} = 5.57\times10^{-8}\text{ cm}$$

$$\text{Radius} = \underbrace{(0.35355)}_{\text{see note above question}}(5.57\times10^{-8}\text{ cm}) = 1.97\times10^{-8}\text{ cm}$$

(This is 1.97×10^{-10} m, which is 1.97 Å)

↑ Angstroms, or 10^{-10} m is a common unit used for molecular distances.

21) What is the mole fraction of ethanol (C_2H_6O, molar mass=46.07g/mol) in a glass of wine? (14%) Density = 0.789 g/mL

$$\text{Mole fraction} = \frac{\text{moles of ethanol}}{\text{moles of ethanol + moles of water}}$$

Ethanol makes up 14mL in 100mL sample

100 − 14 = 86mL H_2O

$$\text{moles of ethanol} = 14\text{mL}\times\frac{0.789\text{ g}}{\text{mL}}\times\frac{\text{mol}}{46.07\text{g}} = 0.24\text{mol}$$

$$\text{moles of water} = 86\text{mL}\times\frac{1\text{g}}{\text{mL}}\times\frac{\text{mol}}{18.0\text{g}} = 4.78\text{mol}$$

$$\text{Mole fraction of ethanol} = \frac{0.24}{4.78+0.24} = 0.048$$

This means that less than 5% of the molecules are ethanol.

22) The freezing point of a glucose solution ($C_6H_{12}O_6$;molar mass= 180.0 g/mole) is - 10.3 ° C . The density of the solution is 1.50 g/ml. What is the molarity of the glucose solution? (K_{fp} for water is 1.86 ° C.kg/mole)

$\Delta T_{fp} = K_{fp} m$ ← molality = $\frac{\text{moles solute}}{\text{kg solvent}}$

$m = \frac{\Delta T_{fp}}{K_{fp}} = \frac{(0-(-10.3°C))}{1.86°C \cdot kg/mole} = 5.54\ mol/kg$ } This is the molality of the solution. To convert to molarity, calculate how many g of solution you have and use the density to determine the volume of the solution.

Assume 1L (=1kg) of solvent. Determine # g of solute:

$5.54mol \times \frac{180.0g}{mole} = 997.2g = 0.997kg$

Mass of solution = 1,000g + 997.2g = 1997.2g
(1,000g: mass of H_2O; 997.2g: mass of glucose)

Volume = $\frac{\text{mass}}{\text{density}} = \frac{1997.2g}{1.50g/mL} = 1,331.5mL = 1.33L$

Molarity = $mol/L = 5.54mol/1.33L = 4.17\ mol/L = \boxed{4.17M}$

23) How many grams of silver bromide must be dissolved in 725 grams of water to make a 0.220 *m* (molal) solution? AgBr molar mass: 107.87 g/mol + 79.904 g/mol = 187.77 g/mol

molality = $\frac{\text{moles solute}}{\text{kg solvent}}$

We need to know the # moles of solute (kg solvent and molality are given).

moles solute = (molality x kg solvent) = $\left(0.220\frac{mol}{kg}\right)(0.725kg) = 0.1595mol$

mol → grams

$0.1595mol \times \frac{187.77g}{mol} = \boxed{29.95g}$

24) If 0.340 mol of a nonvolatile nonelectrolyte are dissolved in 3.00 mol of water, what is the vapor pressure P_{H_2O} of the resulting solution? (The vapor pressure of pure water is 17.5mmHg at 20°C.)

$P_{H_2O} = \chi P^\circ$ $\quad P^\circ = 17.5mmHg$

$\chi = \frac{3mol}{3mol+0.34mol} = 0.898$

$P_{H_2O} = (0.898)(17.5mmHg) = \boxed{15.72\ mmHg}$

25) A sample of 1.20 g of a non-volatile organic compound is dissolved in 60.0 g benzene. The boiling point of the solution is 80.96°C. The boiling point of pure benzene is 80.08°C. What is the molar mass of the solute?

$\Delta T = K_{BP} m$ $\quad K_{bp} = 2.53°C/m$

$m = \frac{\Delta T}{K_{bp}}$

$\Delta T = 80.96°C - 80.08°C = 0.88°C$

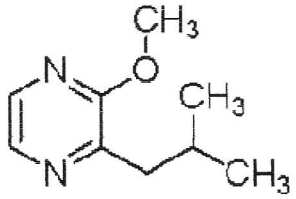
$\frac{\text{moles}}{\text{kg solvent}} = \frac{\Delta T}{K_{bp}}$

$\text{moles} = \frac{\Delta T}{K_{bp}} \times \text{kg solvent} = \frac{0.88°C}{2.53°C/m} \times 0.06\,kg = 0.021\,\text{moles}$

$\text{molar mass} = \frac{1.20\,g}{0.021\,\text{moles}} = \boxed{57.14\,g/\text{mole}}$

EXTRA CREDIT QUESTION

Cabernet Sauvignon grapes have high levels of the flavor compound 3-isobutyl-2-methoxypyrazine (IBMP). This molecule imparts an "herbaceous" flavor and its aroma is that of bell peppers. The structure of IBMP is:



Discuss any properties of this molecule that can be reasonably determined from an examination of its structure (e.g., vapor pressure, boiling point, solubility, hydrogen bonding capability with itself or with water, etc.) This compound is found in wine, an alcohol-water mixture. Does this have an effect on its solubility?

This molecule, on its own, cannot hydrogen bond, so pure IBMP would have a low boiling point and a high vapor pressure. It has a few polar bonds, so dipole interactions as well as induced dipoles affect its boiling point. It is slightly soluble in water because the water H's can form H bonds to the N's and O on the IBMP, but its solubility increases in alcohol because alcohol has some nonpolar portions (CH_3CH_2OH) that have a favorable interaction with the nonpolar portions of the IBMP molecule.