Chemistry 210 Exam 1

Be sure to put your name on each page. This page can be removed from your exam so that you will have a Periodic Table handy throughout the exam, it does not need to be turned in. Show all your work for problems which require any sort of calculation, no credit will be given for answers without work shown. If you have shown a significant amount of work or multiple drawings for a problem, draw a box around what you consider your final answer.

Avogadro's Number = $6.022\times10^{23}\ ^{\text{units}}/_{\text{mol}}$
$32.00^{o}F = 0.000^{o}C = 273.15K$
Density of Water = $1.000\ ^{g}/_{mL}$
$R = 0.08206\ ^{L\bullet atm}/_{mol\bullet K} = 8.314\ ^{J}/_{mol\bullet K}$
$PV=nRT$
$\Delta T_{fp/bp} = k_{fp/bp}\bullet m\bullet i$
For water: $k_{fp} = -1.86\ ^{oC}/_{m}$
$k_{bp} = 0.512\ ^{oC}/_{m}$
$P_1 = X_1P_1^{o}$
$\Pi = MRTi$
$C_1V_1 = C_2V_2$

Quadratic formula:
$$x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$$

Integrated Rate Laws:
$\ln[A]_t = -kt + \ln[A]_o$
$1/[A]_t = kt + 1/[A]_o$
$[A]_t = -kt + [A]_o$
$k = Ae^{-Ea/RT}$
$$\ln(k) = \left(\frac{-E_a}{R}\right)\left(\frac{1}{T}\right) + \ln(A)$$
$$\ln\left(\frac{k_1}{k_2}\right) = \frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$
$$pH = pK_a + \log\left(\frac{[\text{conjugate base}]}{[\text{conjugate acid}]}\right)$$

$E_{cell} = E^{o}_{cell} - {}^{RT}/_{nF}\ \ln Q$
$E^{o}_{cell} = {}^{RT}/_{nF}\ \ln K^{o}$
$K^{o} = e^{\wedge}({}^{nF}/_{RT}\ E^{o}_{cell})$
$F = 96485\ ^{J}/_{V\bullet \text{mol of electrons}}$
$\Delta G^{o} = \Delta H^{o}_{system} - T\Delta S^{o}_{system}$
$\Delta G^{o} = -nFE^{o}_{cell} = -RT\ln K^{o}$
$\Delta G = \Delta G^{o} + RT\ln Q$
$F = 96485\ ^{C}/_{\text{mol electrons}}$
$1A = 1\ C / sec$

1 **H** 1.0079																	2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.0122											5 **B** 10.811	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.180
11 **Na** 22.990	12 **Mg** 24.305											13 **Al** 26.982	14 **Si** 28.086	15 **P** 30.974	16 **S** 32.066	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.88	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.847	27 **Co** 58.933	28 **Ni** 58.69	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.61	33 **As** 74.922	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.03	89 **Ac** 227.03	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)	110 (269)	111 (272)	112 (277)		114		116		

58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.97	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.94	70 **Yb** 173.04	71 **Lu** 174.97
90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** 237.05	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (258)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Score

Multiple Choice (5pts each): Circle the letter of the most correct response.

1. Which of the following is ***not*** a correct ideal gas relationship?
   a. $T_1n_1=T_2n_2$
   b. $T_1/P_1=T_2/P_2$
   c. PV=nRT
   d. $V_1/T_1=V_2/T_2$
   e. $P_1n_1=P_2n_2$

2. Rank the 3 states of matter from lowest kinetic energy to highest kinetic energy.
   a. Solid, liquid, gas
   b. Gas, solid, liquid
   c. Gas, liquid, solid
   d. Liquid, gas, solid
   e. Solid, gas, liquid

3. Which of the following statements is most correct about colligative properties of an ideal solution?
   a. Colligative properties depend upon the number of solute particles, not on the identity of the solute particles.
   b. The presence of a solute lowers the vapor pressure of a solution.
   c. The presence of a solute raises the boiling point of a solution.
   d. The presence of a solute lowers the freezing point of a solution.
   e. These statements are all correct.

4. All of the following concentration units require that you use the molar mass of the solute except:
   a. Molarity
   b. Mass percent
   c. Normality
   d. Molality
   e. Mole fraction

5. When dissolving a solid in a liquid:
   a. Formation of solvent-solute interactions is endothermic
   b. Energy is released (exothermic) by breaking solvent-solvent and solute-solute interactions
   c. The enthalpy of solution is always positive
   d. The boiling point of the solution will be higher than that of the pure solvent
   e. The freezing point of the solution will be higher than that of the pure solvent

6. The volume of a gas:
   a. Is always a constant
   b. Increases as the pressure increases
   c. Decreases as the kinetic energy increases
   d. Increases as the temperature increases
   e. Remains constant as the amount of gas is increased

7. Carbon dioxide (CO_2) has a lower boiling point than sulfur dioxide (SO_2) because:
   a. The bonds in SO_2 are polar but the bonds in CO_2 are not
   b. CO_2 has stronger London dispersion forces than SO_2
   c. SO_2 is a polar molecule but CO_2 is not
   d. SO_2 forms stronger hydrogen bonds than CO_2
   e. CO_2 sublimes

Score

8. A laboratory technician prepares a solution by weighing out 39.225g of potassium bromide and dissolving it in enough water to make 150.00mL of solution. The technician labels the solution "1.3m KBr(aq)". Why is this not correct? What should the laboratory technician do to correct the error? Calculate a correct concentration for this solution. (10pts)

The technician diluted the solution to a known volume, so the correct concentration unit (given the information in the problem) can only be molarity, the label should be "M", not "m". In addition, the technician only reports 2 sig figs, but the data listed in the problem should permit 5 sig figs.

$$\text{Molarity of KBr(aq)} = \left(\frac{\left({39.225\text{g KBr}} \Big/ {119.002\ ^{\text{g}}\!/\!_{\text{mol}}} \right)}{0.15000\text{L solution}} \right) = 2.1974\text{M KBr(aq)}$$

It looks like not only was the unit wrong, but the numerical value was wrong as well, it appears that the technician used the formula "KBr_2" when calculating the formula weight. That technician should look for a different job…

9. You have prepared a solution by dissolving 24.316g of potassium phosphate in enough water to make 500.0mL of solution. What is the *molarity* of this solution? (10pts)

$$\text{Molarity of } K_3PO_4\text{(aq)} = \left(\frac{\left({24.316\text{g } K_3PO_4} \Big/ {212.264\ ^{\text{g}}\!/\!_{\text{mol}}} \right)}{0.5000\text{L solution}} \right) = 0.2291\text{M } K_3PO_4\text{(aq)}$$

10. You have prepared a solution by dissolving 11.617g of ammonium iodide in 100.0g of water. What is the *molality* of this solution? (10pts)

$$\text{Molality of } NH_4I\text{(aq)} = \left(\frac{\left({11.617\text{g } NH_4I} \Big/ {144.94\ ^{\text{g}}\!/\!_{\text{mol}}} \right)}{0.1000\text{kg solvent}} \right) = 0.8015\text{m } NH_4I\text{(aq)}$$

11. You have prepared a solution by diluting 25.00mL of a 3.213M aqueous solution of sugar ($C_6H_{12}O_6$) to a total volume of 150.0mL. What is the *molarity* of this solution? (10pts)

For dilutions, we can use the formula $C_1V_1 = C_2V_2$.

$$(3.213\text{M})(25.00\text{mL}) = C_2(150.0\text{mL})$$

$$C_2 = 0.5355\text{M}$$

Score

12. A 2.00L cylinder contains helium gas at 23.62ºC and 2.93atm pressure. How many grams of He are in the cylinder? (10pts)

This is a single-condition ideal gas law problem, so we should be able to solve it using PV=nRT.

$$P\,V = n\,R\,T$$
$$(2.93\text{atm})\,(2.00\text{L}) = n\,(0.08206\ {}^{\text{L•atm}}/_{\text{mol•K}})\,(296.77\text{K})$$
n = 0.24063mols (I haven't rounded to correct sig figs yet…)
$$(0.24063\text{mols})\,(4.0026\ {}^{\text{g}}/_{\text{mol}}) = 0.963\text{g He}$$

13. What is the freezing point of a solution made by dissolving 24.618g of lithium nitrate in 200.0g of water? (15pts)

$$\text{Molality of } LiNO_3(aq) = \left(\frac{\left(24.618\text{g } LiNO_3 / 68.945\ {}^{\text{g}}/_{\text{mol}}\right)}{0.2000\text{kg solvent}}\right) = 1.7853\text{m } LiNO_3(aq)$$

$$\Delta T_{fp} = k_{fpd} \bullet m \bullet n$$
$$\Delta T_{fp} = (1.86\ {}^{°C}/_{m})(1.7853m)(2\ {}^{\text{mols particles}}/_{\text{mol LiNO3}})$$
$$\Delta T_{fp} = 6.64°C$$

Since freezing point is depressed, the solution will freeze 6.64°C *lower* than the freezing point of the pure solvent, in this case -6.64°C.

14. Each of the following solids is dissolved in separate beakers containing 500.0mL of water. Rank the solutions from lowest vapor pressure to highest vapor pressure and explain your answer. (15pts)
    a. 0.7mols ammonium phosphate
    b. 0.5mols calcium nitrate
    c. 0.4mols magnesium phosphate
    d. 0.6mols sodium chloride

Vapor pressure depression is a colligative property, so the amount that the P_{vap} is depressed depends upon the number of solute particles, not their identity. Let's look at how many solute particles there will be for each of the listed solutes..

0.7mols of $(NH_4)_3PO_4$ yields (3x0.7)+0.7=2.8mols of solute particles

0.5mols of $Ca(NO_3)_2$ yields 3x0.5=1.5mols of solute particles

0.4mols of $Mg_3(PO_4)_2$ dissolve to give 3(0.4mol)=1.2mol of Mg^{2+}(aq) ions and 2(0.4mol)=0.8mol of PO_4^{3-}(aq) ions, for a total of 1.2+0.8=2.0mols of solute particles

0.6mols of NaCl yields 0.6mol of Na^+(aq) and 0.6mol of Cl^-(aq), so 1.2mols of solute particles

The more solute particles, the lower the vapor pressure of the solution, so the ranking should be:

0.7mols of $(NH_4)_3PO_4$ < 0.4mols of $Mg_3(PO_4)_2$ < 0.5mols of $Ca(NO_3)_2$ < 0.6mols of NaCl

Score

15. You have a 76.289g sample of steam (gaseous water) at 135.28°C. Describe what happens to this sample when it is cooled to 41.53°C and calculate the amount of energy transferred during cooling. (15pts)
{C_s(ice) = 2.09 $^{J}/_{g.K}$; C_s(water) = 4.184 $^{J}/_{g.K}$; C_s(steam) = 2.01 $^{J}/_{g.K}$; ΔH_{fusion}(water) = 6.02 $^{kJ}/_{mol}$; $\Delta H_{vaporization}$(water) = 40.7 $^{kJ}/_{mol}$}

From 135.28°C to 100°C, the steam is cooling. At 100°C, the steam condenses. From 100°C to 41.53°C, the liquid water is cooling.

Heat capacity of steam:	(2.01 $^{J}/_{g\bullet K}$)(76.289g)(35.28K)($^{1kJ}/_{1000J}$) = 5.41kJ
Phase change:	(40.7 $^{kJ}/_{mol}$)(76.289g) / (18.015 $^{g}/_{mol}$) = 172kJ
Heat capacity of water:	(4.184 $^{J}/_{g\bullet K}$)(76.289g)(68.47K)($^{1kJ}/_{1000J}$) = 21.86kJ
Total energy transferred:	199kJ

16. A newly discovered protein has been isolated from seeds of a tropical plant and needs to be characterized. A total of 0.126g of this protein was dissolved in enough water to produce 2.00mL of solution. At 33.61°C the osmotic pressure produced by the solution was 0.134atm. What is the molar mass of the protein? (20pts)

This is actually one of the most common ways that osmotic pressure changes are used in real laboratory settings…

$$\Pi = \mathrm{MRT}$$

$$(0.134\text{atm}) = \left(\frac{\left(\frac{0.126g}{x\, ^{g}/_{mol}}\right)}{0.00200 Lsolution}\right)(0.08206\ ^{L\bullet atm}/_{mol\bullet K})(306.76\text{K})$$

$$x = 11800\ ^{g}/_{mol}$$

We're assuming that this protein does not dissociate in solution, so n=1. Proteins are very large molecules, so this molar mass is reasonable.

Score