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 = $6.022\text{x}10^{23}\ ^{\text{units}}/_{\text{mol}}$

$32.00^{\circ}\text{F} = 0.000^{\circ}\text{C} = 273.15\text{K}$

Density of Water = $1.000^{\text{g}}/_{\text{mL}}$

$R = 0.08206\ ^{\text{L}\bullet\text{atm}}/_{\text{mol}\bullet\text{K}} = 8.314\ ^{\text{J}}/_{\text{mol}\bullet\text{K}}$

1atm = 760torr = 760mmHg = 101.325kPa

PV=nRT

$\Delta T_{fp/bp} = k_{fp/bp} \bullet m \bullet i$

For water: $k_{fp} = -1.86^{\circ\text{C}}/_{m}$

$k_{bp} = 0.512^{\circ\text{C}}/_{m}$

$P_1 = X_1 P_1^{o}$

$\Pi = MRTi$

$C_1V_1 = C_2V_2$

Quadratic formula:

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

Integrated Rate Laws:

$\ln[A]_t = -kt + \ln[A]_o$

$1/[A]_t = kt + 1/[A]_o$

$[A]_t = -kt + [A]_o$

$k = Ae^{-Ea/RT}$

$$\ln(k) = \left(\frac{-E_a}{R}\right)\left(\frac{1}{T}\right) + \ln(A)$$

$$\ln\left(\frac{k_1}{k_2}\right) = \frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$pH = pK_a + \log\left(\frac{[\text{conjugate base}]}{[\text{conjugate acid}]}\right)$$

$E_{cell} = E^{o}_{cell} - {}^{RT}/_{nF}\ \ln Q$

$E^{o}_{cell} = {}^{RT}/_{nF}\ \ln K^{o}$

$K^{o} = e\text{^}({}^{nF}/_{RT}\ E^{o}_{cell})$

$F = 96485\ ^{J}/_{V\bullet\text{mol of electrons}}$

$\Delta G^{o} = \Delta H^{o}_{system} - T\Delta S^{o}_{system}$

$\Delta G^{o} = -nFE^{o}_{cell} = -RT\ln K^{o}$

$\Delta G = \Delta G^{o} + RT\ln Q$

$F = 96485\ ^{C}/_{\text{mol electrons}}$

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

2. When dissolving a solid in a liquid:
   a. Energy is released (exothermic) by breaking solvent-solvent and solute-solute interactions
   b. The enthalpy of solution is always positive
   c. Formation of solvent-solute interactions is endothermic
   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

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

4. Under which of the following conditions is a gas ***most*** "ideal"?
   a. Room temperature, 25ºC
   b. High temperature, high pressure
   c. Low temperature, high pressure
   d. Low temperature, low pressure
   e. High temperature, low pressure

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

6. A large positive change in free energy means:
   a. The reaction is very fast
   b. The reaction is exothermic
   c. The reaction is not spontaneous
   d. The system is becoming more disordered
   e. The reaction is spontaneous

7. A reaction will be spontaneous at relatively low temperature and non-spontaneous at relatively high temperature if:
   a. $\Delta H^o_{system} > 0$ and $\Delta S^o_{system} > 0$
   b. $\Delta H^o_{system} < 0$ and $\Delta S^o_{system} > 0$
   c. $\Delta H^o_{system} > 0$ and $\Delta S^o_{system} = 0$
   d. $\Delta H^o_{system} > 0$ and $\Delta S^o_{system} < 0$
   e. $\Delta H^o_{system} < 0$ and $\Delta S^o_{system} < 0$

Score

8. Which of the following is ***not*** a correct gas law relationship?
   a. PV = nRT
   b. $n_1T_1 = n_2T_2$
   c. $V_1 / n_1 = V_2 / n_2$
   d. $P_1V_1 = P_2V_2$
   e. $P_1T_1 = P_2T_2$

Problems: Show your work and write your final answer(s) in the answer box.

9. What is the volume of 2.392mols of ideal gas at 14.38ºC and 2.951atm pressure? (10pts)

$$PV = nRT$$
$$(2.951\text{atm})V = (2.392\text{mol})(0.08206\,{}^{\text{L•atm}}/_{\text{mol•K}})(287.53\text{K})$$
$$V = 19.13\text{L}$$

Answer 9:

19.13L

10. You have prepared a solution by dissolving 16.317g of ammonium nitrate in enough water to make 300.0mL of solution. What is the *molarity* of this solution? (10pts)

$$\frac{\left(\dfrac{16.317\text{g}}{80.0426\,{}^{\text{g}}/_{\text{mol}}}\right)}{0.3000\text{L}} = 0.6795\text{M}$$

Answer 10:

0.6795M

11. You have prepared a solution by dissolving 4.297g of sodium sulfate in 100.0g of water. What is the *molality* of this solution? (sodium atomic # = 11) (10pts)

$$\frac{\left(\dfrac{4.297\text{g}}{142.042\,{}^{\text{g}}/_{\text{mol}}}\right)}{0.1000\text{kg}} = 0.3025\text{M}$$

Answer 11:

0.3025M

12. What is the freezing point of a solution made by dissolving 14.176g of magnesium chlorate in 250.0g of water? (magnesium atomic # = 12) (15pts)

$$\Delta T_{fp} = \left(1.86\,\tfrac{°\text{C}}{\text{m}}\right)\left(\frac{\left(\dfrac{14.176\text{g}}{191.205\,{}^{\text{g}}/_{\text{mol}}}\right)}{0.2500\text{kg}}\right)\left(\frac{3\text{mol "pieces"}}{1\text{mol "formula"}}\right) = 1.65°\text{C}$$

$$T_{fp} = 0.00°\text{C} - 1.65°\text{C} = -1.65°\text{C}$$

Answer 12:

-1.65°C

Score

13. You have reacted 8.042g of magnesium (atomic # = 12) metal with150.0mL of 3.623M HCl(aq) to produce hydrogen gas and magnesium chloride. How many liters of hydrogen gas can be produced at 32.28°C and 1.137atm? (20pts)

$Mg(s) + 2\ HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

If Mg(s) is the limiting reactant:

$$\left(\frac{8.042\text{g Mg}}{24.305\ {}^{\text{g Mg}}/_{\text{mol Mg}}}\right)\left(\frac{1\text{mol H}_2}{1\text{mol Mg}}\right)\left(\frac{(0.08206\ \frac{\text{L}\bullet\text{atm}}{\text{mol}\bullet\text{K}})(305.43\text{K})}{1.137\text{atm}}\right) = 7.294\text{L H}_2(\text{g})$$

If HCl(aq) is the limiting reactant:

$$(0.1500\text{L HCl(aq)})\left(\frac{3.623\text{mol HCl}}{\text{L HCl(aq)}}\right)\left(\frac{1\text{mol H}_2}{2\text{mol HCl}}\right)\left(\frac{(0.08206\ \frac{\text{L}\bullet\text{atm}}{\text{mol}\bullet\text{K}})(305.43\text{K})}{1.137\text{atm}}\right) = 5.990\text{L H}_2(\text{g})$$

Since using all of the available HCl(aq) produces less product, HCl(aq) is the limiting reactant in this mixture and the amount of $H_2(g)$ that can be produced is 5.990L.

Answer 13:

5.990L

14. You are studying a process for which $\Delta H° = -62.81\ {}^{kJ}/_{mol}$ and $\Delta S° = -126.44\ {}^{J}/_{mol\bullet K}$ at 25.00°C. What is ΔG° for this process at 25.00°C? Will the reaction be more or less spontaneous at 20.00°C? (10pts)

$\Delta G° = \Delta H° - T\Delta S°$

$\Delta G° = (-62.81\ {}^{kJ}/_{mol\ rxn}) – (298.15K)(-0.12644\ {}^{kJ}/_{mol\ rxn\bullet K}) = -25.11\ {}^{kJ}/_{mol\ rxn}$

Plugging in for 20.00°C…

$\Delta G° = (-62.81\ {}^{kJ}/_{mol\ rxn}) – (293.15K)(-0.12644\ {}^{kJ}/_{mol\ rxn\bullet K}) = -25.74\ {}^{kJ}/_{mol\ rxn}$

At 20.00°C, ΔG° is more negative, so the reaction will be (slightly) ***more*** spontaneous.

15. Methane {$CH_4(g)$} burns in oxygen to form carbon dioxide and water. How much {Gibb's Free} energy can be liberated by burning 26.831g of methane in an unlimited supply of oxygen? (15pts)

If *gaseous* water is assumed to be a product:

$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g)$

$\Delta G°_{rxn} = 1(+50.81\ {}^{kJ}/_{mol})+2(0\ {}^{kJ}/_{mol})+1(-394.4\ {}^{kJ}/_{mol})+2(+228.6\ {}^{kJ}/_{mol}) = -800.79\ {}^{kJ}/_{mol}$

{$\Delta G°_f$ values were taken from the table at the end of the exam}

$$(26.831\text{g CH}_4)\left(\frac{1\text{mol CH}_4}{16.042\text{g CH}_4}\right)\left(\frac{1\text{mol rxn}}{1\text{mol CH}_4}\right)\left(\frac{800.79\text{kJ}}{1\text{mol rxn}}\right) = 1339.4\text{kJ liberated}$$

If *liquid* water is assumed to be a product:

$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(l)$

$\Delta G°_{rxn} = 1(+50.81\ {}^{kJ}/_{mol})+2(0\ {}^{kJ}/_{mol})+1(-394.4\ {}^{kJ}/_{mol})+2(+237.2\ {}^{kJ}/_{mol}) = -817.99\ {}^{kJ}/_{mol}$

{$\Delta G°_f$ values were taken from the table at the end of the exam}

$$(26.831\text{g CH}_4)\left(\frac{1\text{mol CH}_4}{16.042\text{g CH}_4}\right)\left(\frac{1\text{mol rxn}}{1\text{mol CH}_4}\right)\left(\frac{817.99\text{kJ}}{1\text{mol rxn}}\right) = 1368.1\text{kJ liberated}$$

Answer 15:

1339.4 kJ {for $H_2O(g)$ product}
1368.1 kJ {for $H_2O(l)$ product}

Score

16. How many grams of ethane {$C_2H_6(g)$} would you have to burn to liberate enough Gibb's Free Energy to heat 750.0g of aluminum (atomic # = 13) from 1.08°C to 18.36°C? (Specific heat of Al = $0.902\,{}^{J}/_{g\cdot°C}$) (20pts)

Answer 16:

Step 1: How much energy is required to heat the block of Al?

$$(0.902\,{}^{J}/_{g\cdot°C})(750.0g)(17.28°C)({}^{1kJ}/_{1000J}) = 11.6899kJ \text{ of energy needed.}$$

Step 2: How much ethane has to burn to provide this energy?

If *gaseous* water is assumed to be a product:

$$2\,C_2H_6(g) + 7\,O_2(g) \rightarrow 4\,CO_2(g) + 6\,H_2O(g)$$

$$\Delta G°_{rxn} = 2(+32.0\,{}^{kJ}/_{mol}) + 7(0\,{}^{kJ}/_{mol}) + 4(-394.4\,{}^{kJ}/_{mol}) + 6(+228.6\,{}^{kJ}/_{mol}) = -2885.2\,{}^{kJ}/_{mol}$$

{$\Delta G°_f$ values were taken from the table at the end of the exam}

$$(11.6899kJ)\left(\frac{1mol\ rxn}{2885.2kJ}\right)\left(\frac{1mol\ C_2H_6}{1mol\ rxn}\right)\left(\frac{30.0694g\ C_2H_6}{1mol\ C_2H_6}\right) = 0.246g\ C_2H_6 \text{ required}$$

If *liquid* water is assumed to be a product:

$$2\,C_2H_6(g) + 7\,O_2(g) \rightarrow 4\,CO_2(g) + 6\,H_2O(l)$$

$$\Delta G°_{rxn} = 2(+32.0\,{}^{kJ}/_{mol}) + 7(0\,{}^{kJ}/_{mol}) + 4(-394.4\,{}^{kJ}/_{mol}) + 6(+237.2\,{}^{kJ}/_{mol}) = -2936.8\,{}^{kJ}/_{mol}$$

{$\Delta G°_f$ values were taken from the table at the end of the exam}

$$(11.6899kJ)\left(\frac{1mol\ rxn}{2936.8kJ}\right)\left(\frac{1mol\ C_2H_6}{1mol\ rxn}\right)\left(\frac{30.0694g\ C_2H_6}{1mol\ C_2H_6}\right) = 0.239g\ C_2H_6 \text{ required}$$

{These calculations assume 100% efficiency of the energy transfer from burning C_2H_6 to the aluminum block.}

Thermodynamic Values at 25°C:

Substance	$\Delta H°_f$ (kJ/mol)	S° (J/mol•K)	$\Delta G°_f$ (kJ/mol)
$CH_4(g)$	-74.87	186.61	-50.81
$O_2(g)$	0	+205.138	0
$H_2O(l)$	-285.8	+69.91	-237.2
$H_2O(g)$	-241.8	+188.8	-228.6

Substance	$\Delta H°_f$ (kJ/mol)	S° (J/mol•K)	$\Delta G°_f$ (kJ/mol)
$C_2H_6(g)$	-84.68	+229.2	-32.0
$C_2H_6(g)$	-84.68	+229.2	-32.0
$CO_2(g)$	-393.5	+213.6	-394.4

Score