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 = 6.022×10^{23} $^{\text{units}}/_{\text{mol}}$
$32.00^{\circ}F = 0.000^{\circ}C = 273.15K$
Density of Water = $1.000\ ^{g}/_{mL}$
$R = 0.08206\ ^{L \cdot atm}/_{mol \cdot K} = 8.314\ ^{J}/_{mol \cdot K}$
1atm = 760torr = 760mmHg = 101.325kPa
$PV=nRT$
$\Delta T_{fp/bp} = k_{fp/bp} \bullet m \bullet i$
For water: $k_{fp} = -1.86\ ^{\circ C}/_{m}$
$k_{bp} = 0.512\ ^{\circ C}/_{m}$
$P_1 = X_1 P_1^{\circ}$
$\Pi = MRTi$
$C_1V_1 = C_2V_2$

Integrated Rate Laws:

$$\ln[A]_t = -kt + \ln[A]_o$$
$$1/[A]_t = kt + 1/[A]_o$$
$$[A]_t = -kt + [A]_o$$

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

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

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

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

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

Quadratic formula:

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

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 (4pts 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. 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.

4. 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

5. Under which of the following conditions is a gas ***least*** "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

6. A large negative change in free energy means:
   a. The reaction is very slow
   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 high temperature and non-spontaneous at relatively low 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

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

8. What is the volume of 2.127mols of ideal gas at 19.37ºC and 3.182atm pressure? (10pts)

PV = nRT
(3.182atm)V = (2.127mols)(0.08206 L.atm/mol.K)(273.15+19.37K)
V = 16.05L

Answer 8:

9. You have prepared a solution by dissolving 15.443g of ammonium bromide in enough water to make 250.0mL of solution. What is the *molarity* of this solution? (10pts)

NH_4Br = (14.007g/mol) + 4(1.0079g/mol) + (79.904g/mol) = 97.9426g/mol
(15.443g) / (97.9426g/mol) / (0.2500L) = 0.6307M

Answer 9:

10. You have prepared a solution by dissolving 2.413g of potassium chlorate in 100.0g of water. What is the *molality* of this solution? (10pts)

$KClO_3$ = (39.098g/mol) + (35.453g/mol) + 3(15.999g/mol) = 122.548g/mol
(2.413g) / (122.548g/mol) / (0.1000kg) = 0.1969m

Answer 10:

11. What is the freezing point of a solution made by dissolving 13.861g of magnesium nitrate in 150.0g of water? (15pts)

$Mg(NO_3)_2$ = (24.305g/mol) + 2(14.007g/mol) + 6(15.999g/mol) = 148.313g/mol
(13.861g) / (148.313g/mol) / (0.1500kg) = 0.623052m

$\Delta T_{fp} = k_{fpd}\, m\, i$

ΔT_{fp} = (1.86°C/m)(0.623052m)(3) = 3.48°C

T_{fp} = 0°C – 3.48°C = -3.48°C

Answer 11:

Score

12. You have reacted 8.042g of aluminum metal with150.0mL of 4.623M HCl(aq) to produce hydrogen gas and aluminum chloride. How many liters of hydrogen gas can be produced at 41.61°C and 1.137atm? (20pts)

$2\ Al(s) + 6\ HCl(aq) \rightarrow 3\ H_2(g) + 2\ AlCl_3(aq)$
{(8.042g Al) / (26.982g/mol)}{3mol H_2/2mol Al}{(0.08206L.atm/mol.K)(273.15+41.61K)/(1.137atm)} = 10.16L $H_2(g)$
{(0.1500L HCl)(4.623mol/L)}{3mol H_2/6mol HCl}{(0.08206L.atm/mol.K)(273.15+41.61K)/(1.137atm)} = 7.877L $H_2(g)$

HCl(aq) is the limiting reagent, this mixture can produce 7.877L of $H_2(g)$ assuming 100% yield

13. For each of the following reactions, predict the sign of ΔS° and explain your answer (5pts each):

$$H_2SO_4(aq) + Mg(OH)_2(aq) \Leftrightarrow MgSO_4(s) + 2\ H_2O(l)$$

Solid and liquid forming from 2 aqueous solutions, order is increasing, ΔS should be negative

$$2\ NO_2(g) \Leftrightarrow 2\ NO(g) + O_2(g)$$

All gases… 3 particles forming from 2 particles, disorder is increasing, ΔS should be positive

14. You are studying a process for which $\Delta H° = +47.81\ ^{kJ}/_{mol}$ and $\Delta S° = +63.44\ ^{J}/_{mol \cdot K}$ 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? (12pts)

Answer 14:

ΔG° = ΔH° – TΔS° = (47.81kJ/mol) – (273.15+25.00K)(0.06344kJ/mol.K)
ΔG° = 28.90kJ/mol (not spontaneous)
At 20.00°C, the "-TΔS" term is less spontaneous. Mathematically…
ΔG° = ΔH° – TΔS° = (47.81kJ/mol) – (273.15+20.00K)(0.06344kJ/mol.K)
ΔG° = 29.21kJ/mol (less spontaneous)

15. Ammonia {$NH_3(g)$} can burn in oxygen to form nitrogen dioxide and water. How much {Gibb's Free} energy can be liberated by burning 26.831g of ammonia in an unlimited supply of oxygen? (16pts)

Answer 15:

$4\ NH_3(g) + 7\ O_2(g) \rightarrow 4\ NO_2(g) + 6\ H_2O(g)$
$\Delta G°_{rxn}$ = 4(+16.45kJ/mol) + 7(0kJ/mol) + 4(+51.31kJ/mol) + 6(-228.6kJ/mol) = -1100.56kJ/mol
{(26.831g NH_3) / (17.0307g NH_3/mol NH_3)} (1mol rxn/4mol NH_3) (1100.56kJ/mol rxn) = 433.47kJ

Score

16. How many grams of ethane {$C_2H_6(g)$} would you have to burn to liberate enough Gibb's Free Energy to decompose 17.928g of CaO(s) into Ca(s) and $O_2(g)$? (Assume 100% efficiency.) (20pts)

Answer 16:

Coupled systems problem… First determine how much energy is required to decompose CaO(s)

$2\ CaO(s) \rightarrow 2\ Ca(s) + O_2(g)$

$\Delta G°_{rxn} = 2(+604.0kJ/mol) + 2(0kJ/mol) + 1(0kJ/mol) = +1208.0kJ/mol$

{(17.928g CaO) / (56.077g CaO/mol CaO)}(1mol rxn/2mol CaO)(1208.0kJ/mol rxn) = 193.10kJ

This is the amount of energy required, it has to come from burning ethane:

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

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

{(193.10kJ) / (2885.2kJ/mol rxn)}(2mol C_2H_6/1mol rxn)(30.0694g/mol) = 4.0250g $C_2H_6(g)$

Assuming 100% efficiency…

Thermodynamic Values at 25°C:

Substance	$\Delta H°_f$ ($^{kJ}/_{mol}$)	$S°$ ($^{J}/_{mol \cdot K}$)	$\Delta G°_f$ ($^{kJ}/_{mol}$)
$NH_3(g)$	-46.11	+192.45	-16.45
$O_2(g)$	0	+205.138	0
$NO_2(g)$	+33.18	+240.06	+51.31
$H_2O(g)$	-241.8	+188.8	-228.6
$H_2O(l)$	-285.8	+69.91	-237.2
$C_2H_6(g)$	-84.68	+229.2	-32.0

Substance	$\Delta H°_f$ ($^{kJ}/_{mol}$)	$S°$ ($^{J}/_{mol \cdot K}$)	$\Delta G°_f$ ($^{kJ}/_{mol}$)
$CO_2(g)$	-393.5	+213.6	-394.4
CaO(s)	-635.1	+39.75	-604.0
Ca(s)	0	+41.4	0
$N_2O_4(g)$	+9.16	+304.2	-81.7
$N_2O_5(g)$	+11.3	+355.6	-94.4

Score