

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} units/mol

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

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

$R = 0.08206 \text{ L}\cdot\text{atm}/\text{mol}\cdot\text{K} = 8.314 \text{ J}/\text{mol}\cdot\text{K}$

$1\text{atm} = 760\text{torr} = 760\text{mmHg} = 101.325\text{kPa}$

$PV = nRT$

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

For water: $k_{\text{fp}} = -1.86^\circ\text{C}/m$
 $k_{\text{bp}} = 0.512^\circ\text{C}/m$

$P_1 = X_1 P_1^\circ$

$\Pi = MRTi$

$C_1 V_1 = C_2 V_2$

Integrated Rate Laws:

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

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

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

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

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

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

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

$E_{\text{cell}} = E_{\text{cell}}^\circ - \frac{RT}{nF} \ln Q$

$E_{\text{cell}}^\circ = \frac{RT}{nF} \ln K^\circ$

$K^\circ = e^{(nF/RT) E_{\text{cell}}^\circ}$

$F = 96485 \text{ J}/\text{V}\cdot\text{mol of electrons}$

$\Delta G^\circ = \Delta H^\circ_{\text{system}} - T\Delta S^\circ_{\text{system}}$

$\Delta G^\circ = -nFE_{\text{cell}}^\circ = -RT \ln K^\circ$

$\Delta G = \Delta G^\circ + RT \ln Q$

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

$1A = 1 \text{ C} / \text{sec}$

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)

Multiple Choice (4pts each): Circle the letter of the most correct response.

- Rank the 3 states of matter from highest kinetic energy to lowest kinetic energy.
 - Solid, liquid, gas
 - Solid, gas, liquid
 - Gas, solid, liquid
 - Liquid, gas, solid
 - Gas, liquid, solid**
- When dissolving a solid in a liquid:
 - Energy is released (exothermic) by breaking solvent-solvent and solute-solute interactions
 - The enthalpy of solution is always positive
 - Formation of solvent-solute interactions is endothermic
 - The boiling point of the solution will be higher than that of the pure solvent**
 - The freezing point of the solution will be higher than that of the pure solvent
- Which of the following statements is most correct about colligative properties of an ideal solution?
 - The presence of a solute lowers the boiling point of a solution.
 - The presence of a solute raises the vapor pressure of a solution.
 - Colligative properties depend upon the number of solute particles, not on the identity of the solute particles.**
 - The presence of a solute raises the freezing point of a solution.
 - These statements are all correct.
- The volume of a gas:
 - Decreases as the temperature increases
 - Remains constant as the amount of gas is increased
 - Is always a constant
 - Decreases as the pressure increases**
 - Increases as the kinetic energy increases**
- Under which of the following conditions is a gas *least* “ideal”?
 - Room temperature, 25°C
 - High temperature, high pressure
 - Low temperature, high pressure**
 - Low temperature, low pressure
 - High temperature, low pressure
- A large negative change in free energy means:
 - The reaction is very slow
 - The reaction is exothermic
 - The reaction is not spontaneous
 - The system is becoming more disordered
 - The reaction is spontaneous**
- A reaction will be spontaneous at relatively high temperature and non-spontaneous at relatively low temperature if:
 - $\Delta H^\circ_{\text{system}} > 0$ and $\Delta S^\circ_{\text{system}} > 0$**
 - $\Delta H^\circ_{\text{system}} < 0$ and $\Delta S^\circ_{\text{system}} > 0$
 - $\Delta H^\circ_{\text{system}} > 0$ and $\Delta S^\circ_{\text{system}} = 0$
 - $\Delta H^\circ_{\text{system}} > 0$ and $\Delta S^\circ_{\text{system}} < 0$
 - $\Delta H^\circ_{\text{system}} < 0$ and $\Delta S^\circ_{\text{system}} < 0$

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 19.37°C and 3.182atm pressure? (10pts)

$$\begin{aligned}PV &= nRT \\(3.182\text{atm})V &= (2.127\text{mols})(0.08206 \text{ L}\cdot\text{atm}/\text{mol}\cdot\text{K})(273.15+19.37\text{K}) \\V &= 16.05\text{L}\end{aligned}$$

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)

$$\begin{aligned}\text{NH}_4\text{Br} &= (14.007\text{g}/\text{mol}) + 4(1.0079\text{g}/\text{mol}) + (79.904\text{g}/\text{mol}) = 97.9426\text{g}/\text{mol} \\(15.443\text{g}) / (97.9426\text{g}/\text{mol}) / (0.2500\text{L}) &= 0.6307\text{M}\end{aligned}$$

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)

$$\begin{aligned}\text{KClO}_3 &= (39.098\text{g}/\text{mol}) + (35.453\text{g}/\text{mol}) + 3(15.999\text{g}/\text{mol}) = 122.548\text{g}/\text{mol} \\(2.413\text{g}) / (122.548\text{g}/\text{mol}) / (0.1000\text{kg}) &= 0.1969\text{m}\end{aligned}$$

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)

$$\begin{aligned}\text{Mg}(\text{NO}_3)_2 &= (24.305\text{g}/\text{mol}) + 2(14.007\text{g}/\text{mol}) + 6(15.999\text{g}/\text{mol}) = 148.313\text{g}/\text{mol} \\(13.861\text{g}) / (148.313\text{g}/\text{mol}) / (0.1500\text{kg}) &= 0.623052\text{m}\end{aligned}$$

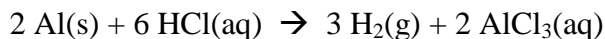
$$\Delta T_{\text{fp}} = k_{\text{fpd}} m i$$

$$\Delta T_{\text{fp}} = (1.86^\circ\text{C}/\text{m})(0.623052\text{m})(3) = 3.48^\circ\text{C}$$

$$T_{\text{fp}} = 0^\circ\text{C} - 3.48^\circ\text{C} = -3.48^\circ\text{C}$$

Answer 11:

12. You have reacted 8.042g of aluminum metal with 150.0mL 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)

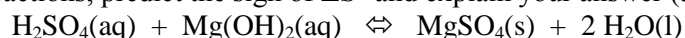


$$\{(8.042\text{g Al}) / (26.982\text{g/mol})\} \{3\text{mol H}_2/2\text{mol Al}\} \{(0.08206\text{L}\cdot\text{atm/mol}\cdot\text{K})(273.15+41.61\text{K}) / (1.137\text{atm})\} = 10.16\text{L H}_2\text{(g)}$$

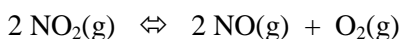
$$\{(0.1500\text{L HCl})(4.623\text{mol/L})\} \{3\text{mol H}_2/6\text{mol HCl}\} \{(0.08206\text{L}\cdot\text{atm/mol}\cdot\text{K})(273.15+41.61\text{K}) / (1.137\text{atm})\} = 7.877\text{L H}_2\text{(g)}$$

HCl(aq) is the limiting reagent, this mixture can produce 7.877L of H₂(g) assuming 100% yield

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



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



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

14. You are studying a process for which $\Delta H^\circ = +47.81\text{kJ/mol}$ and $\Delta S^\circ = +63.44\text{J/mol}\cdot\text{K}$ 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)

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ = (47.81\text{kJ/mol}) - (273.15+25.00\text{K})(0.06344\text{kJ/mol}\cdot\text{K})$$

$$\Delta G^\circ = 28.90\text{kJ/mol (not spontaneous)}$$

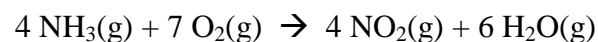
At 20.00°C, the “-T ΔS ” term is less spontaneous. Mathematically...

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ = (47.81\text{kJ/mol}) - (273.15+20.00\text{K})(0.06344\text{kJ/mol}\cdot\text{K})$$

$$\Delta G^\circ = 29.21\text{kJ/mol (less spontaneous)}$$

Answer 14:

15. Ammonia {NH₃(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)



$$\Delta G^\circ_{\text{rxn}} = 4(+16.45\text{kJ/mol}) + 7(0\text{kJ/mol}) + 4(+51.31\text{kJ/mol}) + 6(-228.6\text{kJ/mol}) = -1100.56\text{kJ/mol}$$

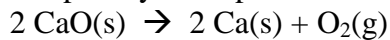
$$\{(26.831\text{g NH}_3) / (17.0307\text{g NH}_3/\text{mol NH}_3)\} (1\text{mol rxn}/4\text{mol NH}_3) (1100.56\text{kJ/mol rxn}) = 433.47\text{kJ}$$

Answer 15:

16. How many grams of ethane {C₂H₆(g)} would you have to burn to liberate enough Gibb's Free Energy to decompose 17.928g of CaO(s) into Ca(s) and O₂(g)? (Assume 100% efficiency.) (20pts)

Answer 16:

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



$$\Delta G^\circ_{\text{rxn}} = 2(+604.0\text{kJ/mol}) + 2(0\text{kJ/mol}) + 1(0\text{kJ/mol}) = +1208.0\text{kJ/mol}$$

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

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



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

$$\{(193.10\text{kJ}) / (2885.2\text{kJ/mol rxn})\}(2\text{mol C}_2\text{H}_6/1\text{mol rxn})(30.0694\text{g/mol}) = 4.0250\text{g C}_2\text{H}_6\text{(g)}$$

Assuming 100% efficiency...

Thermodynamic Values at 25°C:

Substance	ΔH°_f (kJ/mol)	S° (J/mol·K)	ΔG°_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 ₂ O(g)	-241.8	+188.8	-228.6
H ₂ O(l)	-285.8	+69.91	-237.2
C ₂ H ₆ (g)	-84.68	+229.2	-32.0

Substance	ΔH°_f (kJ/mol)	S° (J/mol·K)	ΔG°_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 ₂ O ₄ (g)	+9.16	+304.2	-81.7
N ₂ O ₅ (g)	+11.3	+355.6	-94.4