

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 g/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 kPa

$PV = nRT$

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

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

$P_1 = X_1 P_1^\circ$

$\Pi = MRTi$

$C_1 V_1 = C_2 V_2$

Quadratic formula:

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

Integrated Rate Laws:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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)

Multiple Choice (5pts 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
- 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 *most* “ideal”?
 - Room temperature, 25°C
 - High temperature, high pressure
 - Low temperature, high pressure
 - Low temperature, low pressure
 - High temperature, low pressure
- 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.
- A large positive change in free energy means:
 - The reaction is very fast
 - 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 low temperature and non-spontaneous at relatively high 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 $\Delta S^\circ_{\text{system}} < 0$

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

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 14.38°C and 2.951atm pressure? (10pts)

$$PV = nRT$$

$$(2.951\text{atm})V = (2.392\text{mol})(0.08206\text{L}\cdot\text{atm}/\text{mol}\cdot\text{K})(287.53\text{K})$$

$$V = 19.13\text{L}$$

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)

$$\left(\frac{16.317\text{g}}{80.0426\text{g}/\text{mol}} \right) \frac{1}{0.3000\text{L}} = 0.6795\text{M}$$

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)

$$\left(\frac{4.297\text{g}}{142.042\text{g}/\text{mol}} \right) \frac{1}{0.1000\text{kg}} = 0.3025\text{M}$$

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)

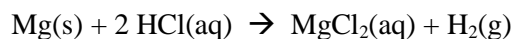
$$\Delta T_{\text{fp}} = \left(1.86 \frac{\text{°C}}{\text{m}} \right) \left(\frac{\left(\frac{14.176\text{g}}{191.205\text{g}/\text{mol}} \right)}{0.2500\text{kg}} \right) \left(\frac{3\text{mol "pieces"}}{1\text{mol "formula"}} \right) = 1.65\text{°C}$$

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

Answer 12:

-1.65°C

13. You have reacted 8.042g of magnesium (atomic # = 12) metal with 150.0mL 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)



If Mg(s) is the limiting reactant:

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

If HCl(aq) is the limiting reactant:

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

Since using all of the available HCl(aq) produces less product, HCl(aq) is the limiting reactant in this mixture and the amount of H₂(g) that can be produced is 5.990L.

Answer 13:

5.990L

14. You are studying a process for which $\Delta H^\circ = -62.81 \text{ kJ/mol}$ and $\Delta S^\circ = -126.44 \text{ J/mol}\cdot\text{K}$ 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? (10pts)

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$\Delta G^\circ = (-62.81 \text{ kJ/mol rxn}) - (298.15\text{K})(-0.12644 \text{ kJ/mol rxn}\cdot\text{K}) = -25.11 \text{ kJ/mol rxn}$$

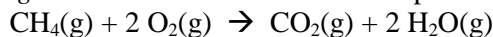
Plugging in for 20.00°C...

$$\Delta G^\circ = (-62.81 \text{ kJ/mol rxn}) - (293.15\text{K})(-0.12644 \text{ kJ/mol rxn}\cdot\text{K}) = -25.74 \text{ kJ/mol rxn}$$

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

15. Methane {CH₄(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:

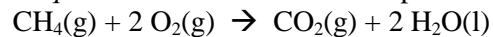


$$\Delta G^\circ_{\text{rxn}} = 1(+50.81 \text{ kJ/mol}) + 2(0 \text{ kJ/mol}) + 1(-394.4 \text{ kJ/mol}) + 2(+228.6 \text{ kJ/mol}) = -800.79 \text{ kJ/mol}$$

{ ΔG°_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:



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

{ ΔG°_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 H₂O(g) product}

1368.1 kJ {for H₂O(l) product}

16. How many grams of ethane {C₂H₆(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·°C}) (20pts)

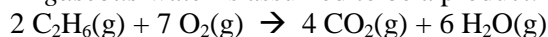
Answer 16:

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

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

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

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

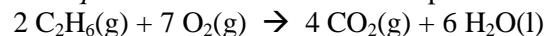


$$\Delta G^\circ_{\text{rxn}} = 2(+32.0 \text{ kJ/mol}) + 7(0 \text{ kJ/mol}) + 4(-394.4 \text{ kJ/mol}) + 6(+228.6 \text{ kJ/mol}) = -2885.2 \text{ kJ/mol}$$

{ΔG_f^o values were taken from the table at the end of the exam}

$$(11.6899\text{kJ}) \left(\frac{1\text{mol rxn}}{2885.2\text{kJ}} \right) \left(\frac{1\text{mol C}_2\text{H}_6}{1\text{mol rxn}} \right) \left(\frac{30.0694\text{g C}_2\text{H}_6}{1\text{mol C}_2\text{H}_6} \right) = 0.246\text{g C}_2\text{H}_6 \text{ required}$$

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



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

{ΔG_f^o values were taken from the table at the end of the exam}

$$(11.6899\text{kJ}) \left(\frac{1\text{mol rxn}}{2936.8\text{kJ}} \right) \left(\frac{1\text{mol C}_2\text{H}_6}{1\text{mol rxn}} \right) \left(\frac{30.0694\text{g C}_2\text{H}_6}{1\text{mol C}_2\text{H}_6} \right) = 0.239\text{g C}_2\text{H}_6 \text{ required}$$

{These calculations assume 100% efficiency of the energy transfer from burning C₂H₆ to the aluminum block.}

Thermodynamic Values at 25°C:

Substance	ΔH _f ^o (kJ/mol)	S ^o (J/mol·K)	ΔG _f ^o (kJ/mol)
CH ₄ (g)	-74.87	186.61	-50.81
O ₂ (g)	0	+205.138	0
H ₂ O(l)	-285.8	+69.91	-237.2
H ₂ O(g)	-241.8	+188.8	-228.6

Substance	ΔH _f ^o (kJ/mol)	S ^o (J/mol·K)	ΔG _f ^o (kJ/mol)
C ₂ H ₆ (g)	-84.68	+229.2	-32.0
C ₂ H ₆ (g)	-84.68	+229.2	-32.0
CO ₂ (g)	-393.5	+213.6	-394.4