

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:

0th $[A]_t = -kt + [A]_o$

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

2nd $1/[A]_t = kt + 1/[A]_o$

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

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

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

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

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

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

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

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

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

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

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

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

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

Quadratic formula:

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

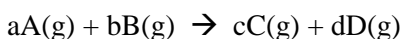
1 H 1.0079																	2 He 4.0026				
3 Li 6.941	4 Be 9.0122															5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
11 Na 22.990	12 Mg 24.305															13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.066	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.078	21 Sc 44.956	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 (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**
- 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 decreases
- 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
- Which of the following does *not* affect the rate of a reaction?
 - The coefficients of the reactants in the balanced equation**
 - The temperature of the system
 - The energy of collisions between reacting particles
 - The frequency of collisions between reacting particles
 - The orientation of colliding particles

6. For the generic equation:



Which of the following is a correct expression of the rate of the reaction:

- $\frac{1}{a} \frac{\Delta[A]}{\Delta t}$
- $k[A]^a[B]^b$
- $-\frac{1}{d} \frac{\Delta[D]}{\Delta t}$
- $k[C]^c[D]^d$
- $-\frac{1}{b} \frac{\Delta[B]}{\Delta t}$**

7. If the rate of a reaction increases by a factor of 9 when the initial concentration of reactant “A” is increased by a factor of 3, the reaction must be:
- 0th order with respect to $[A]_0$
 - 1st order with respect to $[A]_0$
 - 2nd order overall
 - 2nd order with respect to $[A]_0$**
 - The order of the reaction depends on the balanced chemical equation
8. For a second order reaction:
- The slope of the integrated rate law plot is equal to k**
 - The slope of the integrated rate law plot is equal to $(-E_a/R)$
 - The intercept of the integrated rate law is equal to the \ln of the initial concentration
 - The intercept of the integrated rate law plot is equal to the initial concentration
 - The slope of the integrated rate law is equal to the frequency factor, A .
9. Which of the following is *false* regarding reaction mechanisms?
- The observed rate law is equal to the sum of the rate laws from all steps**
 - The observed rate law must agree with the rate law of the slowest step
 - The steps of the mechanism can contain chemical species that do not appear in the overall correctly balanced chemical equation
 - Catalysts can appear in the steps of a mechanism
 - A mechanism must be composed of elementary reactions

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

10. What is the volume of 4.872mols of ideal gas at 36.52°C and 2.917atm pressure? (10pts)

$$PV = nRT$$

$$(2.917\text{atm}) V = (4.872\text{mol}) (0.08206^{\text{L}\cdot\text{atm}/\text{mol}\cdot\text{K}}) (36.52\text{K} + 273.15\text{K})$$

$$V = 42.44\text{L}$$

Answer 10:

11. You have prepared a solution by dissolving 19.715g of ammonium sulfate in enough water to make 250.0mL of solution. What is the *molarity of ammonium ions* in this solution? (12pts)

$$(\text{NH}_4)_2\text{SO}_4 \rightarrow 132.1392^{\text{g}}/\text{mol}$$

$$19.715\text{g } (\text{NH}_4)_2\text{SO}_4 / 132.1392^{\text{g}}/\text{mol } (\text{NH}_4)_2\text{SO}_4 = 0.1491987\text{mol } (\text{NH}_4)_2\text{SO}_4$$

$$(0.1491987\text{mol } (\text{NH}_4)_2\text{SO}_4) / 0.2500\text{L} = 0.596795 \text{ M } (\text{NH}_4)_2\text{SO}_4(\text{aq})$$

$$(0.596795 \text{ M } (\text{NH}_4)_2\text{SO}_4(\text{aq})) (2\text{mol } \text{NH}_4^+(\text{aq}) / 1\text{mol } (\text{NH}_4)_2\text{SO}_4(\text{aq})) =$$

$$1.194\text{M } \text{NH}_4^+(\text{aq})$$

Answer 11:

12. How much energy is required to heat 500.0g of water from -5.38°C to 27.13°C? { $C_s(\text{ice}) = 2.09 \text{ J/g}\cdot\text{K}$; $C_s(\text{water}) = 4.184 \text{ J/g}\cdot\text{K}$; $C_s(\text{steam}) = 2.01 \text{ J/g}\cdot\text{K}$; $\Delta H_{\text{fusion}}(\text{water}) = 6.02 \text{ kJ/mol}$; $\Delta H_{\text{vaporization}}(\text{water}) = 40.7 \text{ kJ/mol}$ } (12pts)

$$\begin{aligned} &\text{Heating solid water from } -5.38^\circ\text{C to } 0^\circ\text{C:} \\ &(2.09 \text{ J/g}\cdot\text{K})(500.0\text{g})(5.38\text{K}) = 5622.1\text{J} \\ &\quad \text{Phase change:} \\ &(6020 \text{ J/mol})(500.0\text{g}/18.015 \text{ g/mol}) = 167080\text{J} \\ &\text{Heating liquid water from } 0^\circ\text{C to } 27.13^\circ\text{C:} \\ &(4.184 \text{ J/g}\cdot\text{K})(500.0\text{g})(27.13\text{K}) = 56756\text{J} \\ &\quad \text{Total energy (heat) required:} \\ &5622\text{J} + 167080\text{J} + 56756\text{J} = 229000\text{J} = 229\text{kJ} \end{aligned}$$

Answer 12:

13. What is the boiling point of a solution made by dissolving 13.861g of calcium nitrate in 150.0g of water? (12pts)

$$\begin{aligned} &\text{Ca(NO}_3)_2 \rightarrow 164.086 \text{ g/mol} \\ &13.861\text{g Ca(NO}_3)_2 / 164.086 \text{ g/mol Ca(NO}_3)_2 = 0.084474\text{mol Ca(NO}_3)_2 \\ &(0.084474\text{mol Ca(NO}_3)_2) / 0.1500\text{kg solvent} = 0.56316\text{m Ca(NO}_3)_2 \text{ (aq)} \\ &\Delta T_{\text{bp}} = (0.512^\circ\text{C/m})(0.56316\text{m Ca(NO}_3)_2 \text{ (aq)}) \left(\frac{3 \text{ mol particles}}{1 \text{ mol solute}} \right) \\ &\quad \Delta T_{\text{bp}} = 0.865^\circ\text{C} \\ &T_{\text{bp}} = 100.000^\circ\text{C} + 0.865^\circ\text{C} = 100.865^\circ\text{C} \end{aligned}$$

Answer 13:

14. A reaction is found to be first order with respect to reactant A and zero order with respect to reactant B. If $[A]_0 = 0.294\text{M}$, $[B]_0 = 0.713\text{M}$ and $k = 6.37 \times 10^{-4} \text{ min}^{-1}$, what is the initial rate of the reaction? (12pts)

$$\begin{aligned} &\text{Rate}_0 = k[A]^1[B]^0 = k[A]^1 \\ &\text{Rate}_0 = (6.37 \times 10^{-4} \text{ min}^{-1})(0.294\text{M}) = 1.87 \times 10^{-4} \text{ M/min} \end{aligned}$$

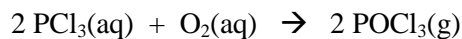
Answer 14:

15. A reaction is found to be zero order with respect to chlorate ion, a reactant. If $[\text{ClO}_3^-]_0 = 2.983\text{M}$ and $k = 7.51 \times 10^{-2} \text{ min}^{-1}$, how much time must pass before the concentration of chlorate ions falls to 0.28M? (12pts)

$$\begin{aligned} &\text{Zeroth order Integrated Rate Law...} \\ &[\text{ClO}_3^-]_t = -kt + [\text{ClO}_3^-]_0 \\ &0.28\text{M} = -(7.51 \times 10^{-2})t + 2.983\text{M} \\ &\quad t = 35.99\text{min} \end{aligned}$$

Answer 15:

16. For the reaction:



You have collected the following data at 23.72°C:

Experiment	$[\text{PCl}_3]_0$	$[\text{O}_2]_0$	Rate _{observed}
1	0.258 M	1.43 M	$4.37 \times 10^{-5} \text{ M}/\text{min}$
2	0.258 M	2.86 M	$8.74 \times 10^{-5} \text{ M}/\text{min}$
3	0.516 M	1.43 M	$1.75 \times 10^{-4} \text{ M}/\text{min}$

What are the rate law and the value of the rate law constant, k, for this reaction?

If you redo Experiment 2 at 2.63°C, the rate is $1.48 \times 10^{-5} \text{ M}/\text{min}$. What is the activation energy for this reaction? (20pts)

Compare 1 & 2: double $[\text{O}_2]_0 \rightarrow$ double rate \rightarrow 1st order w.r.t. $[\text{O}_2]_0$

Compare 1 & 3: double $[\text{PCl}_3]_0 \rightarrow$ 4x rate \rightarrow 2nd order w.r.t. $[\text{PCl}_3]_0$

Plugging in to Exp't 1 to solve for k: $4.37 \times 10^{-5} \text{ M}/\text{min} = k(0.258 \text{ M})^2(1.43 \text{ M}) \rightarrow k = 4.59 \times 10^{-4} \text{ M}^{-2} \text{ min}^{-1}$

$$\text{Rate}_o = (4.59 \times 10^{-4} \text{ M}^{-2} \text{ min}^{-1}) [\text{PCl}_3]_o^2 [\text{O}_2]_o^1$$

At new T, plug in to find new k: $1.48 \times 10^{-5} \text{ M}/\text{min} = k(0.258 \text{ M})^2(2.86 \text{ M}) \rightarrow k = 7.77 \times 10^{-5} \text{ M}^{-2} \text{ min}^{-1}$

Plug into comparative Arrhenius equation...

$$\ln \left(\frac{4.59 \times 10^{-4} \text{ M}^{-2} \text{ min}^{-1}}{7.77 \times 10^{-5} \text{ M}^{-2} \text{ min}^{-1}} \right) = \left(\frac{E_a}{8.314 \text{ J}/\text{mol}\cdot\text{K}} \right) \left(\frac{1}{275.78 \text{ K}} - \frac{1}{296.87 \text{ K}} \right)$$

$$E_a = 57.3 \text{ kJ}/\text{mol}$$

17. 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)

- 0.5mols sodium phosphate
- 0.5mols calcium nitrate
- 0.6mols magnesium chloride
- 0.6mols ammonium carbonate

Since these are all dissolving in the same amount of water, the one with the most solute particles will change the colligative property the most.

a. 0.5mol solute \rightarrow 4 particles per solute dissolved $\rightarrow (0.5 \text{ mol})(4) = 2.0 \text{ mol}$ solute particles

b. 0.5mol solute \rightarrow 3 particles per solute dissolved $\rightarrow (0.5 \text{ mol})(3) = 1.5 \text{ mol}$ solute particles

c. 0.6mol solute \rightarrow 3 particles per solute dissolved $\rightarrow (0.6 \text{ mol})(3) = 1.8 \text{ mol}$ solute particles

d. 0.6mol solute \rightarrow 3 particles per solute dissolved $\rightarrow (0.6 \text{ mol})(3) = 1.8 \text{ mol}$ solute particles

Adding a solute lowers the vapor pressure of the solution, so the lowest vapor pressure should be solution "a", the highest should be solution "b", and solutions "c" and "d" should be the same.

$$a < (c = d) < b$$