

# 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 =  $6.022 \times 10^{23}$  units/mol

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

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

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

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

$PV = nRT$

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

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

$P_1 = X_1 P_1^\circ$

$\Pi = MRTi$

$C_1 V_1 = C_2 V_2$

$E = C_s \cdot g \cdot \Delta T$

Quadratic formula:

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

Integrated Rate Laws:

0<sup>th</sup>  $[A]_t = -kt + [A]_0$

1<sup>st</sup>  $\ln[A]_t = -kt + \ln[A]_0$

2<sup>nd</sup>  $1/[A]_t = kt + 1/[A]_0$

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

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

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

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

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

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

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

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

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

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

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

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

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

1 <b>H</b> 1.0079																	2 <b>He</b> 4.0026				
3 <b>Li</b> 6.941	4 <b>Be</b> 9.0122															5 <b>B</b> 10.811	6 <b>C</b> 12.011	7 <b>N</b> 14.007	8 <b>O</b> 15.999	9 <b>F</b> 18.998	10 <b>Ne</b> 20.180
11 <b>Na</b> 22.990	12 <b>Mg</b> 24.305															13 <b>Al</b> 26.982	14 <b>Si</b> 28.086	15 <b>P</b> 30.974	16 <b>S</b> 32.066	17 <b>Cl</b> 35.453	18 <b>Ar</b> 39.948
19 <b>K</b> 39.098	20 <b>Ca</b> 40.078	21 <b>Sc</b> 44.956	22 <b>Ti</b> 47.88	23 <b>V</b> 50.942	24 <b>Cr</b> 51.996	25 <b>Mn</b> 54.938	26 <b>Fe</b> 55.847	27 <b>Co</b> 58.933	28 <b>Ni</b> 58.69	29 <b>Cu</b> 63.546	30 <b>Zn</b> 65.39	31 <b>Ga</b> 69.723	32 <b>Ge</b> 72.61	33 <b>As</b> 74.922	34 <b>Se</b> 78.96	35 <b>Br</b> 79.904	36 <b>Kr</b> 83.80				
37 <b>Rb</b> 85.468	38 <b>Sr</b> 87.62	39 <b>Y</b> 88.906	40 <b>Zr</b> 91.224	41 <b>Nb</b> 92.906	42 <b>Mo</b> 95.94	43 <b>Tc</b> (98)	44 <b>Ru</b> 101.07	45 <b>Rh</b> 102.91	46 <b>Pd</b> 106.42	47 <b>Ag</b> 107.87	48 <b>Cd</b> 112.41	49 <b>In</b> 114.82	50 <b>Sn</b> 118.71	51 <b>Sb</b> 121.76	52 <b>Te</b> 127.60	53 <b>I</b> 126.90	54 <b>Xe</b> 131.29				
55 <b>Cs</b> 132.91	56 <b>Ba</b> 137.33	57 <b>La</b> 138.91	72 <b>Hf</b> 178.49	73 <b>Ta</b> 180.95	74 <b>W</b> 183.84	75 <b>Re</b> 186.21	76 <b>Os</b> 190.23	77 <b>Ir</b> 192.22	78 <b>Pt</b> 195.08	79 <b>Au</b> 196.97	80 <b>Hg</b> 200.59	81 <b>Tl</b> 204.38	82 <b>Pb</b> 207.2	83 <b>Bi</b> 208.98	84 <b>Po</b> (209)	85 <b>At</b> (210)	86 <b>Rn</b> (222)				
87 <b>Fr</b> (223)	88 <b>Ra</b> 226.03	89 <b>Ac</b> 227.03	104 <b>Rf</b> (261)	105 <b>Db</b> (262)	106 <b>Sg</b> (263)	107 <b>Bh</b> (262)	108 <b>Hs</b> (265)	109 <b>Mt</b> (266)	110 (269)	111 (272)	112 (277)	114		116							

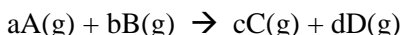
58 <b>Ce</b> 140.12	59 <b>Pr</b> 140.91	60 <b>Nd</b> 144.24	61 <b>Pm</b> (145)	62 <b>Sm</b> 150.36	63 <b>Eu</b> 151.97	64 <b>Gd</b> 157.25	65 <b>Tb</b> 158.93	66 <b>Dy</b> 162.50	67 <b>Ho</b> 164.93	68 <b>Er</b> 167.26	69 <b>Tm</b> 168.94	70 <b>Yb</b> 173.04	71 <b>Lu</b> 174.97
90 <b>Th</b> 232.04	91 <b>Pa</b> 231.04	92 <b>U</b> 238.03	93 <b>Np</b> 237.05	94 <b>Pu</b> (244)	95 <b>Am</b> (243)	96 <b>Cm</b> (247)	97 <b>Bk</b> (247)	98 <b>Cf</b> (251)	99 <b>Es</b> (252)	100 <b>Fm</b> (258)	101 <b>Md</b> (258)	102 <b>No</b> (259)	103 <b>Lr</b> (260)

Score
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**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**
- 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
- Which of the following is *not* a correct gas law relationship?
  - $PV = nRT$
  - $n_1T_1 = n_2T_2$
  - $V_1n_1 = V_2n_2$**
  - $P_1V_1 = P_2V_2$
  - $P_1 / T_1 = P_2 / T_2$
- 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

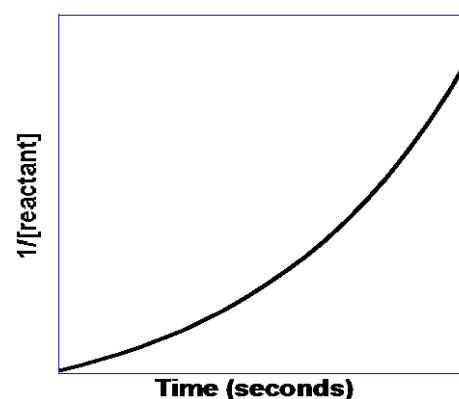
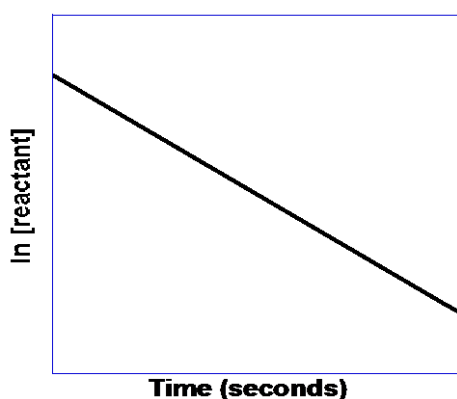
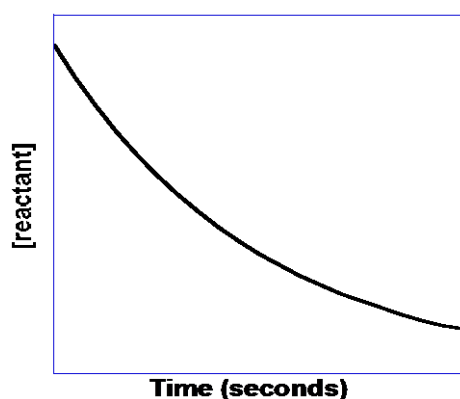
7. For the generic equation:



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

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

8. If the rate of a reaction increases by a factor of 4 when the initial concentration of reactant “A” is increased by a factor of 4, 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
9. 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,  $A$ .



10. The reaction represented by the plots above:
- Is zero order
  - Is first order**
  - Is second order
  - Is third order
  - The order can't be determined by these graphs
11. 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
12. What is the volume of 3.186mols of ideal gas at 23.93°C and 2.11atm pressure? (10pts)

$$\begin{aligned}
 PV &= nRT \\
 (2.11\text{atm}) V &= (3.186\text{mol})(0.08206 \text{ L}\cdot\text{atm}/\text{mol}\cdot\text{K})(297.08\text{K}) \\
 V &= 36.8\text{L}
 \end{aligned}$$

Answer 12:  
36.8 L

13. You have prepared a solution by dissolving 18.146g of magnesium bromide in enough water to make 200.0mL of solution. What is the *molarity of bromide ions* in this solution? {magnesium atomic number = 12} (10pts)

$$18.146\text{g} / 184.113\text{g/mol} = 0.098559\text{mols MgBr}_2$$

$$0.098559\text{mols MgBr}_2 / 0.2000\text{L} = 0.4928\text{M MgBr}_2(\text{aq})$$

$$(0.4928\text{M MgBr}_2(\text{aq})) (2\text{mol Br}^{-1}(\text{aq}) / 1\text{mol MgBr}_2(\text{aq})) = 0.9856\text{M Br}^{-1}(\text{aq})$$

Answer 13:

0.9856M

14. A reaction is found to be zero order with respect to reactant A and second order with respect to reactant B. If  $[A]_0 = 0.573\text{M}$ ,  $[B]_0 = 0.854\text{M}$  and  $k = 1.86 \times 10^{-2} \text{M}^{-1}\text{min}^{-1}$ , what is the initial rate of the reaction? (10pts)

$$\text{Rate}_0 = k [A]_0^0 [B]_0^2 = k [B]_0^2$$

$$\text{Rate}_0 = (1.86 \times 10^{-2} \text{M}^{-1}\text{min}^{-1})(0.854\text{M})^2$$

$$\text{Rate}_0 = 1.36 \times 10^{-2} \text{M/min}$$

Answer 14:

$1.36 \times 10^{-2} \text{M/min}$

15. A reaction is found to be second order with respect to carbonate ion, a reactant. If  $[\text{CO}_3^{2-}]_0 = 2.15\text{M}$  and  $k = 2.19 \times 10^{-3} \text{min}^{-1}$ , how much time must pass before the concentration of carbonate ions falls to 1.03M? (14pts)

Second order integrated rate law...

$$1 / [\text{CO}_3^{2-}]_t = kt + 1 / [\text{CO}_3^{2-}]_0$$

$$1/1.03\text{M} = (2.19 \times 10^{-3} \text{min}^{-1})t + 1/2.15\text{M}$$

$$t = 231 \text{ minutes}$$

Answer 15:

231 minutes

16. What is the boiling point of a solution made by dissolving 17.261g of nickel(II) nitrate in 200.0g of water? (14pts)

$$17.261\text{g} / 182.698\text{g/mol} / 0.2000\text{kg} = 0.47239\text{m Ni}(\text{NO}_3)_2(\text{aq})$$

$$\Delta T_{\text{bp}} = (0.512\text{ }^\circ\text{C/m})(0.47239\text{m})(3\text{ }^{\text{mols particles}} / \text{mol solute}) = 0.726\text{ }^\circ\text{C}$$

$$T_{\text{bp}} = 100.000\text{ }^\circ\text{C} + 0.726\text{ }^\circ\text{C} = 100.726\text{ }^\circ\text{C}$$

Answer 16:

100.726°C

17. How much energy is required to heat 500.0g of water from 17.25°C to 21.39°C?  $\{C_s(\text{ice}) = 2.09 \text{J/g}\cdot\text{K}; C_s(\text{water}) = 4.184 \text{J/g}\cdot\text{K}; C_s(\text{steam}) = 2.01 \text{J/g}\cdot\text{K}; \Delta H_{\text{fusion}}(\text{water}) = 6.02 \text{kJ/mol}; \Delta H_{\text{vaporization}}(\text{water}) = 40.7 \text{kJ/mol}\}$  (14pts)

$$C_s \cdot g \cdot \Delta T = E$$

$$(4.184\text{J/g}\cdot\text{K})(500.0\text{g})(4.14\text{K}) = 8661\text{J} = 8.66\text{kJ}$$

Remember, this is a *change* in temperature, so °C and K are the same. Need proof?

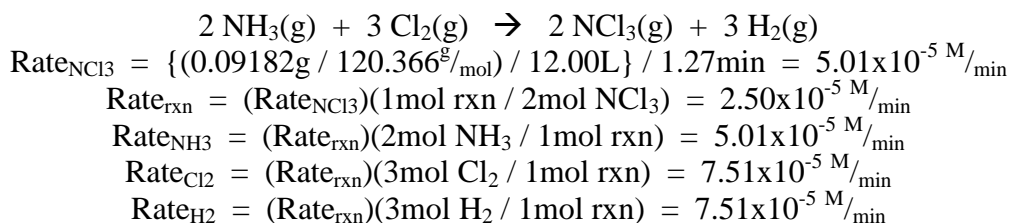
$$\Delta T = 21.39\text{ }^\circ\text{C} - 17.25\text{ }^\circ\text{C} = 4.14\text{ }^\circ\text{C}$$

$$\Delta T = (21.39+273.15)\text{K} - (17.25+273.15)\text{K} = 294.54\text{K} - 290.40\text{K} = 4.14\text{K}$$

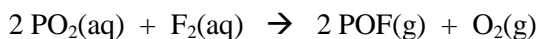
Answer 17:

8.66kJ

18. Ammonia gas reacts with chlorine gas to form nitrogen trichloride gas and hydrogen gas. At some point, 91.82mg of nitrogen trichloride is formed in 1.27 minutes in a 12.00L reaction vessel. What is the rate of the reaction in units of  $M/\text{min}$ ? What are the rates of consumption and production for each reactant and product in the mixture in units of  $M/\text{min}$ ? (18pts)



19. For the reaction:



You have collected the following data at 15.27°C:

Experiment	$[\text{PO}_2]_0$	$[\text{F}_2]_0$	Rate <sub>observed</sub>
1	0.882 M	1.43 M	$2.08 \times 10^{-4} \text{M}/\text{min}$
2	0.882 M	2.86 M	$2.08 \times 10^{-4} \text{M}/\text{min}$
3	0.441 M	1.43 M	$5.41 \times 10^{-5} \text{M}/\text{min}$

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

If you redo Experiment 2 at 33.81°C, the rate is  $1.48 \times 10^{-3} \text{M}/\text{min}$ . What is the activation energy for this reaction? (18pts)

Comparing Exp'ts 1 & 2, doubling  $[\text{F}_2]_0$  does not change the initial rate of the rxn  $\rightarrow 0^{\text{th}}$  order w.r.t.  $[\text{F}_2]_0$   
Comparing Exp'ts 3 & 1, doubling  $[\text{PO}_2]_0$  quadruples the initial rate of the rxn  $\rightarrow 2^{\text{nd}}$  order w.r.t.  $[\text{PO}_2]_0$

$$\text{Rate}_0 = k [\text{PO}_2]_0^2$$

Plugging in numbers from any of the experiments gives  $k_1 = 2.67 \times 10^{-4} \text{M}^{-1}\text{min}^{-1}$  @ 15.27°C (288.42K)

For the redo of Exp't 2, plugging in and re-solving for the "new" value of  $k$ ...

$$1.48 \times 10^{-3} \text{M}/\text{min} = k (0.882\text{M})^2$$

$$k_2 = 1.90 \times 10^{-3} \text{M}^{-1}\text{min}^{-1} \text{ @ } 33.81^\circ\text{C} (306.96\text{K})$$

Plugging in to the comparative form of the Arrhenius equation to solve for activation energy...

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

$$\ln(2.67 \times 10^{-4} \text{M}^{-1}\text{min}^{-1} / 1.90 \times 10^{-3} \text{M}^{-1}\text{min}^{-1}) = (E_a/8.314\text{J/mol}\cdot\text{K})\{(1/306.96\text{K}) - (1/288.42\text{K})\}$$

$$E_a = 7.791 \times 10^4 \text{J/mol} = 77.91 \text{kJ/mol}$$