# *CH 222 Winter 2025:*

# Problem Set #6

# *Instructions*

*Step One (all sections):*

- **Learn the material** for Problem Set #6 by **reading Chapter 12 and Chapter 21** of the textbook and/or by watching the videos found on our website (https://mhchem.org/222)
- **Try the problems** for Problem Set #6 found on the next pages on your own first. **Write out the answers (and show your work) by hand (on a tablet or paper)**; do not type your answers (and work) to avoid a point penalty. If you write the answers on the problem set itself, you will receive fewer points. Include your name on your problem set!

*Step Two:*

*Section 01 and H1:* We will go over Problem Set #6 during recitation. ***Self correct all problems*** of your problem set before turning it in at the end of recitation.

- *Section 01:* due **Monday, March 10 at 1:10 PM**
- *Section H1:* due **Wednesday, March 12 at 1:10 PM**

*Section W1:* **Watch the recitation video** for Problem Set #6 here:

**http://mhchem.org/y/y.htm**

- **Self correct *all* of the problems** while viewing the video. Mark correct problems with a star (or other similar mark), and correct all incorrect problems (show the correct answer and the steps required to achieve it.)
- **Submit Problem Set #6 via email (mike.russell@mhcc.edu) as a single PDF file** (use CamScanner (https://camscanner.com), CombinePDF (https://combinepdf.com), etc.) **by 11:59 PM Wednesday, March 12.**

*If you have any questions regarding this assignment, please email (mike.russell@mhcc.edu) the instructor! Good luck on this assignment!*

# CH 222 Problem Set #6

** Complete problem set on separate pieces of paper showing all work, circling final answers, etc.*
** Self correct your work before turning it in to the instructor.*

*Covering:* ***Chapter Twelve, Chapter Twenty-one*** *and* ***Chapter Guide Six***
*Important Tables and/or Constants:* **R = 8.3145 J mol$^{-1}$ K$^{-1}$**, "**Reaction Mechanisms Guide**" *(Handout)*

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1. Give the equation for the relative rates of disappearance of reactants and formation of products for the following reaction:
   a. $N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$
   b. If $\Delta[H_2]/\Delta t = -4.5 \times 10^{-4}$ M min$^{-1}$, what is $\Delta[NH_3]/\Delta t$?
2. Nitrosyl bromide, NOBr, is formed from NO and $Br_2$. Experiments show that this reaction is second order in NO and first order in $Br_2$. The equation:
   $$2\ NO(g) + Br_2(g) \rightarrow 2\ NOBr(g)$$
   a. Write the rate law equation for the reaction.
   b. How does the initial reaction rate change if the concentration of $Br_2$ is changed from 0.0022 M to 0.0066 M?
   c. What is the change in the initial rate if the concentration of NO is changed from 0.0024 M to 0.0012 M?
3. The reaction:
   $$2\ NO(g) + 2\ H_2(g) \rightarrow N_2(g) + 2\ H_2O(g)$$
   was studied at 904 °C and the data in the table below were collected.

| **Reactant Concentration (M)** | | |
|---|---|---|
| **[NO]** | **[$H_2$]** | **Rate of Appearance of $N_2$ (M s$^{-1}$)** |
| 0.420 | 0.122 | 0.136 |
| 0.210 | 0.122 | 0.0339 |
| 0.210 | 0.244 | 0.0678 |
| 0.105 | 0.488 | 0.0339 |

   a. Determine the order of the reaction for each reactant.
   b. Write the rate law equation for the reaction.
   c. Calculate the rate constant for the reaction.
   d. Find the rate of appearance of $N_2$ at the instant when [NO] = 0.350 M and [$H_2$] = 0.205 M.
4. The decomposition of $N_2O_5$ in $CCl_4$ is a first order reaction. If 2.56 mg of $N_2O_5$ is present initially, and 2.50 mg is present after 4.26 min at 55 °C, what is the value of the rate constant, *k*, at 55 °C?
5. The conversion of cyclopropane to propene occurs with a first order rate constant equal to $5.4 \times 10^{-2}$ h$^{-1}$. How long will it take for the concentration of cyclopropane to decrease from an initial concentration of 0.080 M to 0.020 M?
6. Gold-198 is used in the diagnosis of liver problems. The half-life of $^{198}$Au is 2.69 days. If you begin with 2.8 μg of this gold isotope, what mass remains after 10.8 days?

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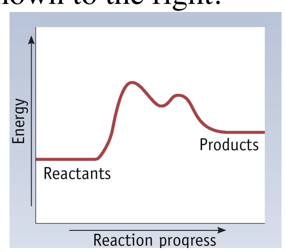
7. Strontium-90 is a hazardous radioactive isotope that resulted from atmospheric testing. A sample of strontium carbonate containing $^{90}Sr$ is found to have an activity of 1.00 x $10^3$ dpm. One (1.00) year later the activity of this sample is 975 dpm.
   a. Calculate the half-life of strontium-90 from this information.
   b. How long will it take for the sample activity to drop to 1.00% of its initial value?
8. Ammonia decomposes when heated according to the equation shown below. The data in the table for this reaction were collected at a high temperature. Plot $[NH_3]$ versus time, ln $[NH_3]$ versus time and $1/[NH_3]$ versus time. What is the order with respect to $NH_3$? Find the rate constant for the reaction from the appropriate slope.

*The reaction:* $NH_3(g) \rightarrow NH_2(g) + H(g)$

| **Time (h)** | **$[NH_3]$ (M)** |
|---|---|
| 0 | 8.00 x $10^{-7}$ |
| 25 | 6.75 x $10^{-7}$ |
| 50 | 5.84 x $10^{-7}$ |
| 75 | 5.15 x $10^{-7}$ |

9. Answer the following questions based on the reaction coordinate diagram shown to the right.
   a. Is the reaction exothermic or endothermic?
   b. Does this reaction occur in more than one step? If so, how many?



*Reaction Diagram*

10. What is the rate law equation for each of the following *elementary* reactions?
    a. $Cl(g) + ICl(g) \rightarrow I(g) + Cl_2(g)$
    b. $O(g) + O_3(g) \rightarrow 2\ O_2(g)$
    c. $2\ NO_2(g) \rightarrow N_2O_4(g)$
11. The reaction of $NO_2(g)$ and $CO(g)$ is thought to occur in two steps:

    **Step 1** (slow) $NO_2(g) + NO_2(g) \rightarrow NO(g) + NO_3(g)$

    **Step 2** (fast) $NO_3(g) + CO(g) \rightarrow NO_2(g) + CO_2(g)$

    a. Add the elementary steps to find the overall, stoichiometric equation.
    b. What is the molecularity of each step? Which step is rate determining?
    c. For this mechanism to be consistent with kinetic data, what must be the experimental rate law equation?
    d. Identify any intermediates and/or catalysts in this reaction.
12. The data in the table below shows the temperature dependence of the rate constant for the reaction $N_2O_5(g) \rightarrow 2\ NO_2(g) + {}^1/_2\ O_2(g)$. Plot these data in the appropriate way to derive the activation energy and frequency factor for the reaction.

| **T(K)** | **$k$($s^{-1}$)** |
|---|---|
| 338 | 4.87 x $10^{-3}$ |
| 328 | 1.50 x $10^{-3}$ |
| 318 | 4.98 x $10^{-4}$ |
| 308 | 1.35 x $10^{-4}$ |
| 298 | 3.46 x $10^{-5}$ |
| 273 | 7.87 x $10^{-7}$ |

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13. Complete the following nuclear equations. Write the mass number, atomic number and symbol for the remaining particle(s).
    a. $^{9}_{4}\text{Be} + ? \rightarrow {}^{6}_{3}\text{Li} + {}^{4}_{2}\text{He}$
    b. $^{241}_{95}\text{Am} + {}^{4}_{2}\text{He} \rightarrow {}^{243}_{97}\text{Bk} + ?$
    c. $^{238}_{92}\text{U} + ? \rightarrow {}^{249}_{100}\text{Fm} + 5\ {}^{1}_{0}\text{n}$
    d. Gallium-67 decays by electron capture.
    e. Potassium-38 decays with positron decay.
    f. Technetium-99m decays with $\gamma$ emission.
14. Calculate the binding energy in kilojoules per mole of nucleons of P for the formation of $^{30}\text{P}$ and $^{31}\text{P}$. The required masses (in grams per mole) are $^{1}_{1}\text{H} = 1.00783$, $^{1}_{0}\text{n} = 1.00867$, $^{30}_{15}\text{P} = 29.97832$ and $^{31}_{15}\text{P} = 30.97376$.