1. Consider the reaction: \(2 \text{N}_2\text{O}_5(g) \rightarrow 4 \text{NO}_2(g) + \text{O}_2(g)\).
   Relate the rate expressions in terms of each reactant and product to each other.

2. The following data were determined at 420°C for the gas-phase reaction
   \(\text{PO}(g) + \text{Cl}_2(g) \leftrightharpoons \text{POCl}_2(g)\)

<table>
<thead>
<tr>
<th>Experiment</th>
<th>[PO] M</th>
<th>[Cl2] M</th>
<th>Initial Rate M \cdot \text{min}^{-1}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.10</td>
<td>0.10</td>
<td>24</td>
</tr>
<tr>
<td>2</td>
<td>0.10</td>
<td>0.20</td>
<td>48</td>
</tr>
<tr>
<td>3</td>
<td>0.40</td>
<td>0.40</td>
<td>1536</td>
</tr>
<tr>
<td>4</td>
<td>0.20</td>
<td>0.40</td>
<td>384</td>
</tr>
</tbody>
</table>

   a. What is the order in PO?
   b. What is the order in Cl2?
   c. What is the overall order?
   d. What is the value of the rate constant at 420°C?
   e. What is the rate at 420°C if \([\text{PO}]_0 = [\text{Cl}_2] = 0.30\) M?

3. Find the activation energy for a reaction having \(k = 3.40 \times 10^{-2}\) at 250 K and \(k = 6.80 \times 10^{-3}\) at 214 K.

4. What is the half life of a reaction that has \([\text{A}]_0 = 0.15\) M and \(k = 2.7 \times 10^6/(\text{M} \cdot \text{s})\).
   What would the half life be if \(k = 2.7 \times 10^6/\text{s}\)?

5. A proposed mechanism for the reaction: \(\text{H}_2 + \text{Br}_2 \rightarrow 2 \text{HBr}\) (hv is light energy)
   (i) \(\text{Br}_2 + \text{hv} \rightarrow 2 \text{Br}\) rate constant, \(k_1\)
   (ii) \(2 \text{Br} + 2 \text{H}_2 \rightarrow 2 \text{HBr} + 2 \text{H}\) rate constant, \(k_2\)
   (iii) \(\text{H} + \text{Br}_2 \rightarrow \text{HBr} + \text{Br}\) rate constant, \(k_3\)
   (iv) \(\text{H} + \text{HBr} \rightarrow \text{H}_2 + \text{Br}\) rate constant, \(k_4\)
   (v) \(\text{Br} + \text{Br} \rightarrow \text{Br}_2\) rate constant, \(k_5\)
   a. If step (i) is the rate–determining step, what is the rate law expression?
   b. Is there a catalyst? (CIRCLE ONE) YES NO If so, what is it?
   c. Is there an intermediate? (CIRCLE ONE) YES NO If so, what is it?

6. a. Calculate the concentrations of all substances present in the equilibrium mixture at a given temperature if 2.35 mol \(\text{H}_2\) and 2.35 mol \(\text{I}_2\) are placed in a 10.0 L flask and allowed to come to equilibrium, at which time 3.76 mol \(\text{HI}\) is present. The balanced chemical reaction is
   \(\text{H}_2(g) + \text{I}_2(g) \leftrightharpoons 2 \text{HI}(g)\)
   b. What is \(K_c\) for the reaction?
   c. What is \(K_c\) at the same temperature for the following reaction? \(2 \text{HI}(g) \leftrightharpoons \text{H}_2(g) + \text{I}_2(g)\)

7. The following concentrations were found present in a reaction flask: \([\text{CS}_2] = 0.48\) M, \([\text{H}_2] = 0.35\) M, \([\text{CH}_4] = 0.42\) M, \([\text{H}_2\text{S}] = 0.52\) M. The relevant reaction follows. Is the reaction at equilibrium? If not, in which direction is the reaction proceeding?
   \(\text{CS}_2(g) + 4 \text{H}_2(g) \leftrightharpoons \text{CH}_4(g) + 2 \text{H}_2\text{S}(g); K_c = 0.28.\)
8. Write the equilibrium constant expression, \( K_c \), for each of the following reactions:
   a. \( 2 \text{Fe}(s) + 4 \text{H}_2\text{O}(g) \rightleftharpoons \text{Fe}_2\text{O}_4(s) + 4 \text{H}_2(g) \)
   b. \( 2 \text{NO}_2(g) + 7 \text{H}_2(g) \rightleftharpoons 2 \text{NH}_3(g) + 4 \text{H}_2\text{O}(g) \)
   c. \( 2 \text{CaSO}_4(s) \rightleftharpoons \text{CaO}(s) + 2 \text{SO}_2(g) + \text{O}_2(g) \)

9. Calculate the equilibrium concentration of CO in the reaction below, if the initial concentration of \( \text{CO}_2 \) and \( \text{H}_2 \) is 2.50 M. \( K_c = 0.0667 \). The reaction is:
   \( \text{CO}_2(g) + \text{H}_2(g) \rightleftharpoons \text{CO}(g) + \text{H}_2\text{O}(g) \)

10. What is the composition of the equilibrium mixture if you begin with 0.25 mol each of \( \text{H}_2 \) and \( \text{I}_2 \) in a 5.0 L vessel:
    \( \text{H}_2(g) + \text{I}_2(g) \rightleftharpoons 2 \text{HI}(g) \); \( K_c = 49.7 \) at 458°C

11. Given the following equilibrium for the exothermic reaction:
    \( \text{Co(H}_2\text{O)}_{6}^{2+}(aq) + 4 \text{Cl}^-(aq) \rightleftharpoons \text{CoCl}_4^{2-}(aq) + 6 \text{H}_2\text{O}(l) \)
    What would you expect to see in each of the following situations?
    b. Lowering the temperature? Explain.
    c. Adding water? Explain.

12. Identify each of the following:
    a. the conjugate acid of \( \text{H}_2\text{PO}_4^- \)
    b. the conjugate base of \( \text{H}_2\text{PO}_4^- \)
    c. the conjugate acid of \( \text{HS}^- \)
    d. the conjugate base of \( \text{HS}^- \)

13. a. Which is the stronger acid: \( \text{HOClO}_3 \) or \( \text{HOClF}_3 \)? Explain.
    b. Which is the stronger acid: \( \text{HOClO}_3 \) or \( \text{HOBrO}_3 \)? Explain.
    c. Which is the stronger acid: \( \text{HBr} \) or \( \text{HF} \)? Explain.
    d. Which is the stronger acid: \( \text{H}_2\text{SO}_3 \) or \( \text{HSO}_3^- \)? Explain.

14. Given a 2.45 x 10^{-5}M solution of \( \text{Ba(OH)}_2 \)
    a. What is the pH of the solution?
    b. What is the pOH of the solution?
    c. What is the [\( \text{H}_3\text{O}^+ \)]?
    d. What is the [\( \text{OH}^- \)]?
    e. Is the solution (CIRCLE ONE) ACIDIC BASIC NEUTRAL?