1. If 14.0 g of CO₂ gas has a volume of 2.3×10⁴ mL at 28 °C, what is its pressure, in atm?

2. 1.50 atm of wet ammonia gas is dried, then decreased from 78.0 mL to 40.0 mL at constant temperature. What is the final pressure of dry ammonia, in mm Hg, if P_{H₂O} = 28.3 mm Hg when the gas was collected?

3. A scuba tank gas mixture contains 3.0 grams of oxygen to every 97.0 grams of helium. What is the partial pressure of oxygen when this mixture is delivered at a total pressure of 8.7 atm?
4. A 6.100 g sample of an ideal gas in a 2.00 L container is held at a constant pressure of 0.900 atm and a constant temperature of 290.0 K. Calculate the molar mass of the gas.

5. (a) Draw accurate, 3-D structures for PCl$_3$ and PCl$_5$ including all lone pairs. Draw a crossed arrow to show the molecular dipole for the polar compound.

(b) Which compound would boil at the higher temperature? Justify your answer, using intermolecular forces to explain the differences.

6. Identify the primary intermolecular force experienced by pure samples of (a) through (d).

(a) H$_2$S  (b) CH$_3$OH  (c) H$_3$C-CH$_2$-CH$_3$  (d) He

(e) Rank these in order of increasing vapor pressure (at the same temperature).

7. Which of the following molecules can form hydrogen bonds with other molecules of the same kind? Circle your answer(s).

CH$_3$F  CH$_3$NH$_2$  H$_2$O  HI  CH$_3$-O-CH$_3$  CHCl$_3$  HCOOH
8. Ethylene glycol, C\textsubscript{2}H\textsubscript{6}O\textsubscript{2}, is a component of automobile antifreeze. If a 35.0 mass\% solution of ethylene glycol in water is prepared at 20 °C, and the density of the solution is 1.154 g/mL, what is the molarity of the solution?

9. The density of a 0.5000 M solution of glucose (M\text{glucose} = 180.2 g/mol) in water is 2.026 g/mL.
   (a) Calculate the boiling point of this solution, in °C.

   (b) Calculate the vapor pressure of this solution at 25 °C, in mm Hg, if the vapor pressure of H\textsubscript{2}O at 25 °C is 23.8 mm Hg.

11. Strontium-90 is a radioactive isotope that is a product of an atomic bomb explosion. It has a half-life of 28.1 years. How long will it take for a 50.0 g sample of Sr-90 to decay to 5.00 g?

   What will the mass of the sample be after 28.1 years?  __________ g
12. The initial rates listed were measured in methanol solution for the reaction:
\[ C_2H_4Br_2 + 3 I^- \rightarrow C_2H_4 + 2 Br^- + I_3^- \]

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Initial [C2H4Br2]</th>
<th>Initial [I^-]</th>
<th>Initial Rate of I3^- Made (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.127 M</td>
<td>0.102 M</td>
<td>6.45\times10^{-5}</td>
</tr>
<tr>
<td>2</td>
<td>0.343 M</td>
<td>0.102 M</td>
<td>1.74\times10^{-4}</td>
</tr>
<tr>
<td>3</td>
<td>0.203 M</td>
<td>0.125 M</td>
<td>1.26\times10^{-4}</td>
</tr>
</tbody>
</table>

(a) Which experiments must be compared first in order to find the order with respect to one of the reactants?

(b) What is the overall order of the reaction?

(c) Calculate the rate constant, \( k \), with units.

13. A decomposition reaction at 25 °C has a frequency factor of 1.0 \times 10^{-3} \text{ s}^{-1} and activation energy of 50.0 \text{ kJ/mol}. What is the rate constant of the reaction?

14. Write the equilibrium expression, \( K_c \), for the reaction
\[ CH_3COOH \text{ (aq)} + H_2O \text{ (l)} \rightleftharpoons CH_3COO^- \text{ (aq)} + H_3O^+ \text{ (aq)} \]
What type of \( K \) value does this represent, more specifically? (Circle one)

\[ K_c = \]

\( K_i \quad K_a \quad K_b \quad K_w \quad K_p \quad K_{sp} \)
15. At 298 K, there is typically much more molecular oxygen than ozone in the air. Oxygen and ozone convert according to the reaction \( 3 \text{O}_2(g) \leftrightarrow 2 \text{O}_3(g) \).

(a) If \(0.0520 \, \text{M} \text{O}_3\) and no oxygen is loaded into a container, and the equilibrium concentration of \(\text{O}_3\) is \(9.28 \times 10^{-32} \, \text{M} \text{O}_3\), create an ICE table to find, numerically, the equilibrium concentration of \(\text{O}_2\).

(b) Calculate \(K_c\) at this temperature.

(c) Explain why the value of \(K_c\) supports the amount of oxygen and ozone found in the air.

16. Consider the reaction \(2 \text{SO}_2(g) + \text{O}_2(g) \leftrightarrow 2 \text{SO}_3(g)\) at a certain temperature.

(a) If the initial pressures of \(\text{SO}_2\), \(\text{O}_2\), and \(\text{SO}_3\) are 0.400 atm, 0.750 atm, and 0.132 atm, respectively, calculate \(Q_p\) for this reaction.

(b) If the equilibrium partial pressure of \(\text{O}_2\) is 0.600 atm, calculate the equilibrium pressures of \(\text{SO}_2\) and \(\text{SO}_3\).
(c) Calculate $K_p$ at this temperature. Does your value of $K$ make sense? ($K$ vs. $Q$)

17. Which will have the higher pH? You do not need to show your work.

(a) 0.200 M KOH or 0.200 M Ba(OH)$_2$?

(b) 0.0500 M HClO$_4$ or 0.0500 M HF?

(c) 1.00 M IO$_3^-$ ($K_a$ of HIO$_3$ is $1.7 \times 10^{-1}$) or 1.00 M C$_3$H$_5$O$_3^-$ ($K_a$ of HC$_3$H$_5$O$_3$ is $1.4 \times 10^{-4}$).

*Hint: Still don’t need work!

18. Circle the correct equilibrium position shift and effect on the value of $K$ for the reaction $(\text{CH}_3)_2\text{CHOH} (g) \rightleftharpoons (\text{CH}_3)_2\text{CO} (g) + \text{H}_2 (g)$, for which $\Delta H^\circ = +57.3$ kJ.

<table>
<thead>
<tr>
<th>STRESS</th>
<th>EQUILIBRIUM POSITION SHIFT</th>
<th>NUMERICAL VALUE OF $K$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) temperature is increased</td>
<td>Left, No Shift, Right</td>
<td>Lower, No Change, Higher</td>
</tr>
<tr>
<td>(b) volume is increased</td>
<td>Left, No Shift, Right</td>
<td>Lower, No Change, Higher</td>
</tr>
<tr>
<td>(c) H$_2$ is added</td>
<td>Left, No Shift, Right</td>
<td>Lower, No Change, Higher</td>
</tr>
<tr>
<td>(d) a catalyst is added</td>
<td>Left, No Shift, Right</td>
<td>Lower, No Change, Higher</td>
</tr>
</tbody>
</table>

19. Below are mechanisms for a catalyzed and an uncatalyzed reaction. Write the overall rate law for each, circle any catalysts, and put a box around any intermediates.

\[
\begin{align*}
\text{Step 1: } & \quad \text{O}_3 (g) \xrightarrow{k_1} \text{O}_2 (g) + \text{O} (g) \quad \text{(fast)} \\
\text{Step 2: } & \quad \text{O}_3 (g) + \text{O} (g) \rightarrow 2 \text{O}_2 (g) \quad \text{(slow)}
\end{align*}
\]

\[
\begin{align*}
\text{Step 1: } & \quad \text{O}_3 (g) + \text{NO}(g) \rightarrow \text{NO}_2(g) + \text{O}_2(g) \quad \text{(slow)} \\
\text{Step 2: } & \quad \text{O}_3(g) \rightarrow \text{O}_2(g) + \text{O}(g) \quad \text{(fast)} \\
\text{Step 3: } & \quad \text{NO}_2(g) + \text{O}(g) \rightarrow \text{NO}(g) + \text{O}_2(g) \quad \text{(fast)}
\end{align*}
\]
20. (a) Trifluoroacetic acid, CF₃COOH, is one of the strongest weak acids. Calculate the $K_a$ of CF₃COOH if a 0.150 $M$ sample has a pH of 1.020.

(b) Calculate the percent ionization of this sample.

21. Decide whether each compound will form acidic, basic, or neutral solutions:

(a) calcium carbonate

acidic  neutral  basic

(b) KCl

acidic  neutral  basic

(c) ammonium nitrate

acidic  neutral  basic

(d) NH₄CN given $K_b$ (NH₃) = 1.8×10⁻⁵ and $K_a$ (HCN) = 4.9×10⁻¹⁰

acidic  neutral  basic
22. Consider a buffer made from HNO$_2$(aq) and NaOH(aq). $K_a$(HNO$_2$) = 4.5$\times$10$^{-4}$. Suppose 10.0 g of solid NaOH were added into 2.00 L of 1.00 $M$ HNO$_2$. Calculate the pH of the buffer.

23. A 50.0 mL sample of 0.100 $M$ sodium hypochlorite is titrated with 0.200 $M$ HCl. ($K_a$(HClO) = 2.9$\times$10$^{-8}$)
Calculate the pH after the addition of each of the following volumes of acid:
(a) 12.5 mL
(b) 25 mL
24. Calculate the value of the thermodynamic equilibrium constant $K$ for the following reaction.

$$\text{C(graphite)} + \text{O}_2(g) \rightarrow \text{CO}_2(g)$$

Standard Free Energies of Formation (at 25 °C)

<table>
<thead>
<tr>
<th>Formula</th>
<th>$\Delta G_f^\circ$ (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO$_2$</td>
<td>-394.4</td>
</tr>
</tbody>
</table>

25. For the reaction

$$\text{CH}_3\text{OH(l)} + \frac{3}{2} \text{O}_2(g) \rightarrow 2\text{H}_2\text{O(l)} + \text{CO}_2(g)$$

the value of $\Delta G^\circ$ is -702.6 kJ at 25 °C. Other data are as follows:

<table>
<thead>
<tr>
<th></th>
<th>$\Delta H_f^\circ$ (kJ/mol) at 25 °C</th>
<th>$S^\circ$ (J/mol·K) 25 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH$_3$OH(l)</td>
<td>-238.6</td>
<td>127</td>
</tr>
<tr>
<td>H$_2$O(l)</td>
<td>-285.8</td>
<td>70</td>
</tr>
<tr>
<td>CO$_2$</td>
<td>-393.5</td>
<td>214</td>
</tr>
</tbody>
</table>

Calculate the absolute entropy, $S^\circ$, per mole of O$_2$(g).
26. (a) Calculate the standard free energy change, ΔG°, for the following at 25 °C:
MgO(s) + C(graphite) → Mg(s) + CO(g)

\[ \Delta H^\circ = 491.18 \text{ kJ} \quad \Delta S^\circ = 197.67 \text{ J/K} \]

(b) Is this reaction spontaneous at 25 °C? If not, at what temperature can we make this reaction spontaneous?