1) Curve A below shows the distribution of kinetic energies for Cl\textsubscript{2} at 298 K. Curves B, C, D, and E are plotted with the same axes using the same axis scales as Curve A. Which curve best represents the distribution of kinetic energies for Ne at 298 K?

![Kinetic energy fraction graph](image)

2) The van der Waals constants for four gases are shown below. The van der Waals equation is given on the formula sheet attached to the back of the exam.

<table>
<thead>
<tr>
<th>Gas</th>
<th>a (L\textsuperscript{2} atm/mol\textsuperscript{2})</th>
<th>b (L/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N\textsubscript{2}</td>
<td>1.39</td>
<td>0.0391</td>
</tr>
<tr>
<td>H\textsubscript{2}O</td>
<td>5.46</td>
<td>0.0305</td>
</tr>
<tr>
<td>CH\textsubscript{4}</td>
<td>2.25</td>
<td>0.0428</td>
</tr>
<tr>
<td>CO\textsubscript{2}</td>
<td>3.59</td>
<td>0.0427</td>
</tr>
</tbody>
</table>

Based on these values, which of the following statements is reasonable?

a) H\textsubscript{2}O molecules occupy more space than CH\textsubscript{4} molecules.

b) There are stronger attractive forces between CO\textsubscript{2} molecules than there are between N\textsubscript{2} molecules.

c) The tendency of CO\textsubscript{2} molecules to attract each other is similar to the tendency of CH\textsubscript{4} molecules to attract each other.

d) Both A and B are reasonable.

e) Both A and C are reasonable.

3) A sample of ethanol (C\textsubscript{2}H\textsubscript{5}OH, molar mass = 46.07 g/mol, density = 0.7893 g/mL) contains 4.79 x 10\textsuperscript{21} molecules. What is the volume of the sample in milliliters?

4) 16.55 g of CO reacts with an excess of an unknown element M to form 23.04 g of a compound that has the chemical formula M\textsubscript{2}(CO)\textsubscript{10}. Using this information, determine the atomic weight of element M.
5) In an acid-base titration, 13.85 mL of 0.0867 M H₃PO₄ is reacted with 22.50 mL of aqueous KOH to reach an endpoint. Determine the molarity of the KOH solution. The chemical reaction in this titration is: H₃PO₄(aq) + 3 KOH(aq) → K₃PO₄(aq) + 3 H₂O(l).

6) Write balanced net ionic equations for the reactions that occur when the following solutions are mixed.
   a) 0.1 M AgNO₃ and 0.1 M Na₂S
   b) 0.1 M HCN and 0.1 M Ba(OH)₂ (Note: HCN is a weak acid, and no precipitate forms in this reaction.)
   c) 0.1 M CuSO₄ and 0.1 M BaBr₂

7) When 9.50 mL of 0.300 M CaCl₂ is combined with 8.50 mL of 0.200 M K₃PO₄, the following reaction takes place:
   3 Ca²⁺(aq) + 2 PO₄³⁻(aq) → Ca₃(PO₄)₂(s)
Based on this information, fill in the partial material balance table below. Show your work in the space below the table. (Note: the molar mass of Ca₃(PO₄)₂ is 310.18 g/mol.)

<table>
<thead>
<tr>
<th>Species</th>
<th>Initial number of millimoles</th>
<th>Final number of millimoles</th>
<th>Final molarity or mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca²⁺(aq)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cl⁻ (aq)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ca₃(PO₄)₂(s)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8) For each of the following descriptions, give the chemical formula of a compound that matches the description.
   a) A strong acid
   b) A compound that contains Fe³⁺ and is insoluble in water
   c) A compound that contains PO₄³⁻ and is soluble in water

9) A solution is made by dissolving 15.75 g of MgCl₂ in enough water to make 250.0 mL of solution.
   a) What is the molar concentration of chloride ions in this solution?
   b) How much water must be added to this solution in order to decrease the concentration of chloride to 0.500 M?

10) A laboratory worker carries out the reaction shown below using an excess of oxygen.
    4 PH₃(g) + 8 O₂(g) → P₄O₁₀(s) + 6 H₂O(g)
She obtains 68.90 g of solid P₄O₁₀, which represents an 81.93% yield. How many grams of PH₃ did she use?

11) Naproxen is an analgesic (pain reliever) and an anti-pyretic (fever reducer). When 8.623 g of Naproxen is combusted, 21.057 g of CO₂, 6.034 g of H₂O, and 0.670 g of N₂ are formed. (These are the only products of the combustion.) The molar mass of Naproxen is 360.4 g/mol. Determine the molecular formula of Naproxen.
12) A solution contains one or more of the following ions: \( \text{SO}_4^{2-} \), \( \text{CO}_3^{2-} \), and \( \text{PO}_4^{3-} \). The following experiments are carried out on this solution:

   Experiment A: When 0.1 M \( \text{MgCl}_2 \) is added to the original solution, a white precipitate forms.
   Experiment B: When 0.1 M \( \text{BaCl}_2 \) is added to the supernatant from experiment A, a white precipitate forms.
   Experiment C: When 6 M HCl is added to a fresh portion of the original solution, there is no visible reaction.

Use this information to fill in the table below.

<table>
<thead>
<tr>
<th>Ion</th>
<th>Does the original solution contain this ion?</th>
<th>How can you tell? (No credit unless you explain your reasoning here!)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{SO}_4^{2-} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \text{CO}_3^{2-} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \text{PO}_4^{3-} )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

13) A solution contains the ions \( \text{SO}_4^{2-} \) and \( \text{Cl}^- \). The total concentration for these two ions together is 0.503 M. When 12.50 mL of this solution is treated with excess \( \text{Pb}^{2+} \), 1.541 g of combined solid products is obtained. From this information, determine the molarities of \( \text{SO}_4^{2-} \) and \( \text{Cl}^- \) in the original solution.

14) Three gases are placed in identical containers and the average velocities of the atoms in each sample are determined:
   - Sample A: 1 mole of He, average velocity = 1000 m/sec
   - Sample B: 1.2 moles of Ar, average velocity = 400 m/sec
   - Sample C: 1.4 moles of Xe, average velocity = 150 m/sec

   Arrange the three gases in order from lowest to highest temperature, and explain your reasoning clearly. Do not just write algebraic equations!

15) At 22.0°C at a pressure of 752 torr, a gas has a density of 1.39 g/L. What is the molar mass of the gas?

16) Unknown gas G is 78.16% B and 21.84% H by mass. Gas G effuses through a porous barrier at a rate of 6.45 mL/sec. \( \text{CF}_4 \) gas effuses through the same barrier under the same conditions at a rate of 3.62 mL/sec. Determine the molecular formula of gas G.

17) Two sealed gas containers are separated by a valve. Container A has a volume equal to 0.460 L and contains acetylene (\( \text{C}_2\text{H}_2 \)) gas at 30.0°C at a pressure of 1.15 atm. Container B has a volume equal to 0.615 L and contains oxygen at 30.0°C at a pressure of 5.60 atm. The valve is opened and the gases react by the following equation:

   \[
   2 \text{C}_2\text{H}_2(g) + 5 \text{O}_2(g) \longrightarrow 4 \text{CO}_2(g) + 2 \text{H}_2\text{O}(l)
   \]

   Determine the total gas pressure in the two containers after the reaction at 30.0°C.

18) Determine the kinetic energy of a sulfur hexafluoride molecule that has a velocity of 165 m/sec. Give your answer in J and in kJ/mol.