**Simple Mole Concept Calculations Using Equations**

The mole concept is the chemists way with dealing with amounts of STUFF called matter (compounds, molecules, atoms, ions, atomic particles, etc.). The mole concept can be summarized by the (“mole triangle”) figure below. It shows the relations between moles of stuff ($n_S$), particles of stuff ($p_S$) and Avogadro's number ($N_A = 6.022 \times 10^{23}$ particles/mol), and mass of stuff ($m_S$) and molar mass of stuff ($M_S$).

Mole concept calculations for all stuff can be completely defined by the use of three equations derived from the “mole triangle:”

The first equation shows that a mole of stuff is equal to the mass of stuff divided by the molar mass of that stuff:

$$ n_S = \frac{m_S}{M_S} $$

Any mole concept problem dealing with moles of a substance and mass of that substance can be solved using this equation. The second equation shows that a mole of stuff is equal to the number of particles of that stuff divided by Avogadro’s number:

$$ n_S = \frac{p_S}{N_A} $$

Any mole concept problem dealing with moles of a substance and particles of that substance can be solved using this equation. The final equation shows the relation of mass of stuff and particles of that stuff. The equation is:

$$ \frac{m_S}{M_S} = \frac{p_S}{N_A} $$

Any mole concept problem dealing with mass of a substance and particles of that substance can be solved using this equation.

It is a **must** that students memorize these three equations. **All** mole concept problems can be solved using the correct equation for the data given in a mole concept calculation.

To make mole concept calculations the student should follow three steps: First, carefully analyze the problem to determine the kind of information given in the problem (mole, mass, particles), determine which of the equations above will be used to solve the problem, and write down the equation. Second, read the problem again and write the values of the known information given in the problem and the value of the
unknown as equalities either under or beside the equation from the first step. Remember that Avogadro's number is always known, and molar mass can always be calculated from the formula of the compound given in the problem. Last, substitute the values of all of the variables determined in the second step into the equation determined in the first step and solve for the unknown using the method of solving a linear equation or ratio-and-proportion.

Example 1: How many molecules of \( \text{C}_4\text{H}_{10}\text{O} \) are in 0.345 moles of \( \text{C}_4\text{H}_{10}\text{O} \)?

**Step 1—Analysis:** This problem deals with particles (molecules) and moles—equation (2) fits this problem with \( p_s \) being the unknown to be calculated.

\[
n_S = \frac{p_s}{N_A}
\]

**Step 2—Variable Values:**
- \( n_S = 0.345 \) mol (of \( \text{C}_4\text{H}_{10}\text{O} \))
- \( p_s = x \) (to be calculated)
- \( N_A = 6.022 \times 10^{23} \) molecules/mol

**Step 3—Solution:**
\[
0.345 \text{ mol} = \frac{x}{6.022 \times 10^{23} \text{ molecules/mol}}
\]

\[
x = (0.345 \text{ mol})(6.022 \times 10^{23} \text{ molecules/mol})
\]

\[
x = 2.08 \times 10^{23} \text{ molecules}
\]

Example 2: Determine the mass of 25 molecules of \( \text{C}_4\text{H}_{10}\text{O} \).

**Step 1—Analysis:** This problem deals with particles (molecules) and mass—equation (3) fits this problem with \( m_s \) being the unknown to be calculated.

\[
\frac{m_S}{M_S} = \frac{p_s}{N_A}
\]

**Step 2—Variable Values:**
- \( p_s = 25 \) molecules
- \( m_s = x \) (to be calculated)
- \( N_A = 6.022 \times 10^{23} \) molecules/mol
- \( M_S = 74.0 \) g/mol (calculated from formula)

**Step 3—Solution:**
\[
\frac{x}{74.0 \text{ g/mol}} = \frac{25 \text{ molecules}}{6.022 \times 10^{23} \text{ molecules/mol}}
\]

\[
x = \frac{25}{74.0} \times 6.022 \times 10^{23} \text{ mol}
\]

\[
x = 3.07 \times 10^{-21} \text{ g}
\]

Example 3: How many moles of \( \text{C}_4\text{H}_{10}\text{O} \) are in 25.6 g of \( \text{C}_4\text{H}_{10}\text{O} \)?

**Step 1—Analysis:** This problem deals with mass and moles—equation (1) fits this problem with \( n_s \) being the unknown to be calculated.

\[
n_S = \frac{m_S}{M_S}
\]
Step 2—Variable Values: \( m_S = 25.6 \) g (of \( \text{C}_4\text{H}_{10}\text{O} \)).
\( n_S = x \) (to be calculated)
\( M_S = 74.0 \text{ g/mol} \) (calculated from formula)

Step 3—Solution:
\[
\frac{25.6 \text{ g}}{74.0 \text{ g/mol}} = x
\]
\( x = 0.346 \text{ mol} \)

Example 4: 4.56 billion molecules of \( \text{C}_4\text{H}_{10}\text{O} \) is how many moles of \( \text{C}_4\text{H}_{10}\text{O} \)?

Step 1—Analysis: This problem deals with particles (molecules) and moles—equation (2) fits this problem with \( n_S \) being the unknown to be calculated.

\[
\frac{P_S}{N_A}
\]

Step 2—Variable Values: \( P_S = 4.56 \) billion molecules = \( 4.56 \times 10^9 \) molecules
\( n_S = x \) (to be calculated)
\( N_A = 6.022 \times 10^{23} \) molecules/mol

Step 3—Solution:
\[
\frac{4.56 \times 10^9 \text{ molecules}}{6.022 \times 10^{23} \text{ molecules/mol}} = x
\]
\( x = 7.57 \times 10^{-15} \text{ mol} \)

Example 5: 98.6 g of \( \text{C}_4\text{H}_{10}\text{O} \) contains how many molecules?

Step 1—Analysis: This problem deals with particles (molecules) and mass—equation (3) fits the problem with \( m_s \) being the unknown to be calculated.

\[
\frac{m_S}{M_S} = \frac{P_S}{N_A}
\]

Step 2—Variable Values: \( m_S = 98.6 \) g (of \( \text{C}_4\text{H}_{10}\text{O} \)).
\( P_S = x \) (to be calculated)
\( N_A = 6.022 \times 10^{23} \) molecules/mol
\( M_S = 74.0 \text{ g/mol} \) (calculated from formula)

Step 3—Solution:
\[
\frac{98.6 \text{ g}}{74.0 \text{ g/mol}} = \frac{x}{6.022 \times 10^{23} \text{ molecules/mol}}
\]
\( 1.332 \text{ mol} = \frac{x}{6.022 \times 10^{23} \text{ molecules/mol}}
\]
\( x = 8.03 \times 10^{23} \text{ molecules} \)

Example 6: Determine the mass of 2.03 moles of \( \text{C}_4\text{H}_{10}\text{O} \).

Step 1—Analysis: This problem deals with mass and moles—equation (1) fits the problem with \( m_s \) being the unknown to be calculated.

\[
\frac{m_S}{M_S} = \frac{P_S}{N_A}
\]
Step 2—Variable Values:

\[ n_S = 2.03 \text{ moles} \]
\[ m_S = x \]
\[ M_S = 74.0 \text{ g/mol (calculated from formula)} \]

Step 3—Solution:

\[
\begin{align*}
2.02 \text{ mol} &= \frac{x}{74.0 \text{ g/mol}} \\
x &= (2.03 \text{ mol})(74.0 \text{ g/mol}) \\
x &= 150 \text{ g}
\end{align*}
\]

Each of these examples is a typical mole concept calculation. The "triangle method" of deriving equations relating moles, mass and particles is simple to learn. The analysis of mole concept problems is easy and quickly mastered. Substituting known and unknown information into the equation derived to solve a problem leaves a linear equation or ratio-and-proportion calculation that students should easily be able to simplify and solve.