**Balancing Chemical Equations Using Matrices**

Boron sulfide and water violently react to from boric acid and hydrogen sulfide. The unbalanced equation is:

$$\\_\\_B\_{2}S\_{3}+\\_\\_H\_{2}O\rightarrow \\_\\_H\_{3}BO\_{3}+\\_\\_H\_{2}S$$

We assign unknown variables to each the equation above as follows:

$$aB\_{2}S\_{3}+bH\_{2}O\rightarrow cH\_{3}BO\_{3}+dH\_{2}S$$

and rewrite the equation:

$$aB\_{2}S\_{3}+bH\_{2}O-cH\_{3}BO\_{3}-dH\_{2}S=0$$

This chemical formula/mathematical equation implies separate equations for boron, sulfur, oxygen and hydrogen as follows:

|  |  |
| --- | --- |
| Boron | $$2a+0b-1c-0d=0$$ |
| Sulfur | $$3a+0b-0c-d=0$$ |
| Hydrogen | $$0a+2b-3c-2d=0$$ |
| Oxygen | $$0a+b-3c-0d=0$$ |

We can rewrite this in augmented matrix form:

$$\left[\begin{matrix}\begin{matrix}\begin{matrix}2\\3\\\begin{matrix}0\\0\end{matrix}\end{matrix}&\begin{matrix}0\\0\\\begin{matrix}2\\1\end{matrix}\end{matrix}\end{matrix}&\begin{matrix}\begin{matrix}-1\\ 0\\\begin{matrix}-3\\-3\end{matrix}\end{matrix}&\begin{matrix} 0\\-1\\\begin{matrix}-2\\ 0\end{matrix}\end{matrix}\end{matrix}&\begin{matrix}0\\0\\\begin{matrix}0\\0\end{matrix}\end{matrix}\end{matrix}\right]$$

Enter this matrix into your calculator and execute the RREF function:

$$\left[\begin{matrix}\begin{matrix}\begin{matrix}1\\0\\\begin{matrix}0\\0\end{matrix}\end{matrix}&\begin{matrix}0\\1\\\begin{matrix}0\\0\end{matrix}\end{matrix}\end{matrix}&\begin{matrix}\begin{matrix}0\\0\\\begin{matrix}1\\0\end{matrix}\end{matrix}&\begin{matrix} -1/3\\-2\\\begin{matrix}-2/3\\ 0\end{matrix}\end{matrix}\end{matrix}&\begin{matrix}0\\0\\\begin{matrix}0\\0\end{matrix}\end{matrix}\end{matrix}\right]$$

Note the last row implies that there are an infinite number of solutions, but that’s OK, we only need one. This matrix represents the following set of equations:

$\left\{\begin{array}{c}a-\frac{1}{3}d=0\\b-2d=0\\c-\frac{2}{3}d=0\end{array}\right.$ or $\left\{\begin{array}{c}a=\frac{1}{3}d\\b=2d\\c=\frac{2}{3}d\end{array}\right.$

Now select a value for $d$that is equal to the least common denominator for the fractions in the final set of equations, i.e. $d=3$. Therefore $a=1, b=6, and c=2$. We now have the balanced equation:

$$B\_{2}S\_{3}+6H\_{2}O\rightarrow 2H\_{3}BO\_{3}+3H\_{2}S$$

**Homework:**

Apply this method to balance the following chemical equations:

1. Burning propane:

$$\\_\\_C\_{3}H\_{8}+\\_\\_O\_{2}\rightarrow \\_\\_CO\_{2}+\\_\\_H\_{2}0$$

1. “Plop, plop, fizz, fizz, Oh what a relief it is” … The Alka-Selzer Reaction

$$\\_\\_NaHCO\_{3}+\\_\\_H\_{3}C\_{6}H\_{5}O\_{7}\rightarrow \\_\\_Na\_{3}C\_{6}H\_{5}O\_{7}+\\_\\_H\_{2}0+\\_\\_CO\_{2}$$

1. Fun with parathesis …

$$\\_\\_Na\_{3}PO\_{4}+\\_\\_Ba\left(NO\_{3}\right)\_{2}\rightarrow \\_\\_Ba\_{3}\left(PO\_{4}\right)\_{2}+\\_\\_NaNO\_{3}$$