Phosphorus in Plant Food

Calculation Guide

Plant food has been historically analyzed by combustion analysis. Combustion analysis involves burning a substance X and measuring the mass of each oxygen compound produced. The %P_2O_5 reported on the label of the plant food is the percent that results from burning some quantity, and dividing the amount of P_2O_5 that would be produced by the original mass.

$$X + O_{2\,(g)} \rightarrow CO_{2\,(g)} + H_2O_{(g)} + NO_{2\,(g)} + K_2O_{(s)} + P_2O_{5\,(g)}$$

We want to check the %P_2O_5 claim on the label. But we're going to use a different kind of analysis to do that, gravimetric analysis.

Gravimetric analysis is the quantitative isolation of a substance by precipitation and the weighing of the precipitate. Follow the four steps below when solving gravimetric calculations.

1) Find moles of precipitate
2) Find moles of sought substance (you'll do this for P first, then P_2O_5)
3) Find mass of sought substance
4) Calculate the percentage of the sample that is the sought substance

Example: If a 10.00 g sample of soluble plant food yields 10.22 g of $MgNH_4PO_4 \cdot 6H_2O$, what are the percentages of P and P_2O_5 in this sample?

<u>First, calculate the percentage of P, phosphorous in the sample</u>:

1) The moles of precipitate are given by: $(10.22\text{ g } MgNH_4PO_4 \cdot 6H_2O)\left(\frac{1\text{ mol } MgNH_4PO_4 \cdot 6H_2O}{245.4\text{ g } MgNH_4PO_4 \cdot 6H_2O}\right)$

2) Since there is 1 mol of P in 1 mol of $MgNH_4PO_4 \cdot 6H_2O_{(s)}$, we can find the moles of phosphorous (the sought substance) if we multiply the above expression by: $\left(\frac{1\text{ mol P}}{1\text{ mol } MgNH_4PO_4 \cdot 6H_2O}\right)$

Putting the two together we have:

$$(10.22\text{ g } MgNH_4PO_4 \cdot 6H_2O)\left(\frac{1\text{ mol } MgNH_4PO_4 \cdot 6H_2O}{245.4\text{ g } MgNH_4PO_4 \cdot 6H_2O}\right) \times \left(\frac{1\text{ mol P}}{1\text{ mol } MgNH_4PO_4 \cdot 6H_2O}\right)$$

3) The mass of phosphorous is determined by the factor: $\left(\frac{30.97\text{ g P}}{1\text{ mol P}}\right)$

which is the mass of 1 mole of phosphorous (its molar mass).

Combining the various expressions we get:

$$(10.22\text{ g } MgNH_4PO_4 \cdot 6H_2O)\left(\frac{1\text{ mol } MgNH_4PO_4 \cdot 6H_2O}{245.4\text{ g } MgNH_4PO_4 \cdot 6H_2O}\right) \times \left(\frac{1\text{ mol P}}{1\text{ mol } MgNH_4PO_4 \cdot 6H_2O}\right)\left(\frac{30.97\text{ g P}}{1\text{ mol P}}\right) = 1.290\text{ g P}$$

4) The percentage of phosphorous in the sample is given by the expression:

$$\%P = \frac{\text{g P}}{\text{g sample}} \times 100 = \frac{1.290\text{ g P}}{10.00\text{ g sample}} \times 100 = 12.90\%\text{ P}$$

Next, calculate the percentage of P_2O_5 that would have been produced if we burned the sample.

1) The moles of precipitate are given by:

$$(10.22 \text{ g MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O})\left(\frac{1 \text{ mol MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}}{245.4 \text{ g MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}}\right)$$

(which is the same as step 1 in the previous calculation since the mass of ppt is unchanged).

2) Since there is 1 mol of P in 1 mol of $MgNH_4PO_4{\cdot}6H_2O_{(s)}$, we can find the moles of phosphorous if we multiply the above expression by:

So far we have

$$(10.22 \text{ g MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O})\left(\frac{1 \text{ mol MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}}{245.4 \text{ g MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}}\right) \times \left(\frac{1 \text{ mol P}}{1 \text{ mol MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}}\right)$$

which is the same as step 2 in the previous calculation, however, our sought substance is P_2O_5, not P, so we must use an additional factor to convert moles of P to moles of P_2O_5:

$$\left(\frac{1 \text{ mol P}_2\text{O}_5}{2 \text{ mol P}}\right)$$

We use this factor because there are 2 moles of P in every 1 mole of P_2O_5.

We may then write:

$$(10.22 \text{ g MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O})\left(\frac{1 \text{ mol MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}}{245.4 \text{ g MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}}\right)\left(\frac{1 \text{ mol P}}{1 \text{ mol MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}}\right)\left(\frac{1 \text{ mol P}_2\text{O}_5}{2 \text{ mol P}}\right)$$

3) The mass of P_2O_5 is determined by multiplying the above expression by:

which is the mass of 1 mole of P_2O_5.

The final expression is:

$$(10.22 \text{ g MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O})\left(\frac{1 \text{ mol MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}}{245.4 \text{ g MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}}\right)\left(\frac{1 \text{ mol P}}{1 \text{ mol MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}}\right)\left(\frac{1 \text{ mol P}_2\text{O}_5}{2 \text{ mol P}}\right)\left(\frac{141.9 \text{ g P}_2\text{O}_5}{1 \text{ mol P}_2\text{O}_5}\right) = 2.955 \text{ g P}_2\text{O}_5$$

4) The percentage of P_2O_5 in the sample is given by:

$$\% \text{ P}_2\text{O}_5 = \frac{2.955 \text{ g}}{10.00 \text{ g}} \times 100 = 29.55\% \text{ P}_2\text{O}_5$$

Reminder, $\%P_2O_5$ appears as the label claim on the plant food box.