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## Chemistry in a coffee cup: does coffee waste contain key elements for plant growth?

# Phosphate answer sheet

**What phosphate concentration did you observe?**

In this example, the observed phosphate concentration was 0.25 ppm (mg/l) of $PO_4^{3-}$.

**In NPK fertilizers, does P refer to phosphorus, phosphates, or phosphorus pentoxide?**

In NPK fertilizers, P refers to phosphorus pentoxide ($P_2O_5$) and not to elemental phosphorus or phosphate ions. It represents the percentage by mass of $P_2O_5$, a standard way of expressing phosphorus content in fertilizers.

**How many milligrams of $P_2O_5$ are present in the measured mass of coffee waste?**

Based on a measured phosphate concentration of 0.25 ppm (milligrams of phosphate per litre of solution), and using relative molar masses to convert phosphate ($PO_4^{3-}$) into phosphorus pentoxide ($P_2O_5$), we estimate that the coffee waste used contains approximately 118 mg of $P_2O_5$ per kilogram. This value shows that coffee grounds contain a small but measurable amount of plant-available phosphorus.

Step-by-step calculations:

1. Convert ppm into mg of $PO_4^{3-}$ in 10 ml test sample:

$2.5\ mg/l \times 0.010\ l = 2.5 \times 10^{-3}\ mg$

2. Scale to 100 ml:

$(2.5 \times 10^{-3}\ mg \times 0.100\ l) \div 0.010\ l = 2.5 \times 10^{-2}\ mg$

This is the same content found in the 5 ml sample taken from the original 200 ml coffee solution.

3. Scale to the original sample (200 ml extract):

To find the content in 200 ml, multiply by 200/5, that is, 40:

$2.5 \times 10^{-2}\ mg \times 40 = 1.0\ mg$ of $PO_4^{3-}$

4. Phosphate content per kilogram of waste (Assuming all the $PO_4^{3-}$ is extracted):

6.34 g coffee = 0.00634 kg

(1.0 mg $PO_4^{3-}$ × 1.0 kg coffee) ÷ 0.00634 kg coffee = 158 mg $PO_4^{3-}$

5. Conversion to $P_2O_5$:

Molar mass $PO_4^{3-}$: 95 g/mol

Molar mass $P_2O_5$: 141.95 g/mol

(158 mg $PO_4^{3-}$ ÷ 95 g/mol) × 141.95 g/mol = 118 mg $P_2O_5$

**How do high levels of phosphate affect plant growth and aquatic ecosystems?**

Phosphate is essential for plants, supporting root growth, seed development, and energy transfer (ATP). However, in excess, it causes eutrophication in water bodies: an overgrowth of algae followed by oxygen depletion, which harms aquatic life