

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

Chemistry of the aquarium test kits

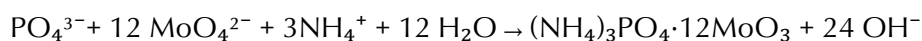
These test kits often use proprietary reagents, so in the reagents are listed as just A and B, which makes it difficult to know what reactions are taking place. Based on a little literature research,^[1,2] we can suggest the following reactions (or something similar) as plausible candidates.

Phosphate Test

Suggested mechanism: formation of a phosphomolybdate complex and then reduction to a blue complex.^[1]

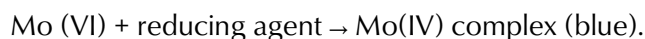
Formation of phosphomolybdic acid

In an acidic solution (typically sulfuric acid), orthophosphate ions (PO_4^{3-}) react with ammonium molybdate and sometimes with potassium antimony tartrate to form a phosphomolybdic complex:



Reduction to molybdenum blue

In the presence of a reducing agent such as ascorbic acid (or stannous chloride), this complex is reduced to a blue compound known as molybdenum blue:



Potassium antimonyl tartrate is added to speed up the reaction and suppress interference.

Why the color changes

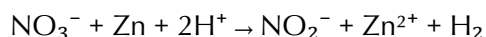
The original yellow complex is a weak absorber of light. Upon reduction, some of the Mo(VI) is converted to Mo(IV), forming mixed valence molybdenum oxides. These form delocalized electron systems that strongly absorb visible light, producing the intense blue color. The intensity of the blue color is directly proportional to the concentration of phosphate in the sample.

Nitrate Test

Suggested mechanism: Griess reaction after reduction of nitrate to nitrite.^[2]

Reduction of nitrate ion (NO_3^-) to nitrite (NO_2^-)

This step is either chemical or physical, depending on the kit (can occur with zinc powder or other metal reducing agents):



Griess reaction

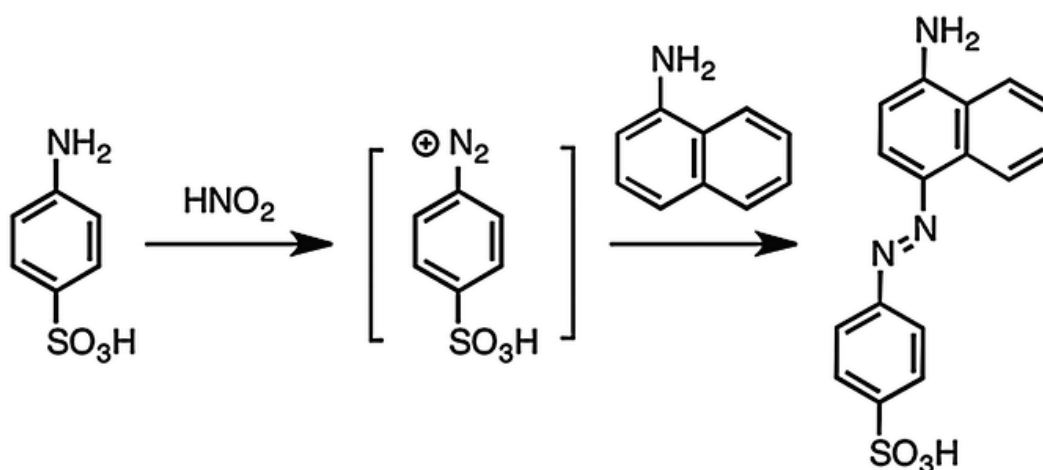
If nitrite is present, the following sequence takes place:

Step 1- Diazotation:

Nitrite in an acidic environment reacts with sulfanilic acid (or a variant thereof) to form a diazonium salt (Ar-N_2^+)

Step 2- Azo coupling reaction:

Diazonium couples with 1-naphthylamine to form a colored compound, a pink or violet azo dye.



Griess reaction with sulphanilic acid and 1-naphthylamine in acid solution

Image: Cisco79/[Wikimedia Commons](#), [CC BY-SA 4.0](#)

Why the colour changes

The final azo compound has an extended conjugated double bond, which absorbs visible light. The intensity of the color is proportional to the concentration of the initial nitrate ion.



References

- [1] Habibah N et al. (2018) [A Simple Spectrophotometric Method for the Quantitative Analysis of Phosphate in Water Samples](#). *International Journal of Analytical Chemistry* **7**: 198–204. doi: 10.23887/jst-undiksha.v7i2.13940
- [2] Wongniramaikul W et al. (2022) [Portable Colorimetric Hydrogel Test Kits and On-Mobile Digital Image Colorimetry for On-Site Determination of Nutrients in Water](#). *Molecules* **27**: 7287. doi: 10.3390/molecules27217287