

Phosphorus (P) - Student Datasheet

Atomic number 15 - Nonmetal - pnictogen - Group 15 - Period 3 - p-block

Phosphorus is element 15, a Group 15 nonmetal with five valence electrons and radically different allotropes. White P₄, red phosphorus and layered black phosphorus show how bonding and structure can transform the behavior of the same element.

Quick reference

Atomic number	15
Relative atomic mass	30.974
Electron configuration	[Ne] 3s ² 3p ³
State at 20 C	Solid nonmetal at 20 deg C - allotrope-dependent
Density	1.823 g/cm ³ - white phosphorus reference
Melting point	317.3 K - white phosphorus reference
Boiling point	553.7 K - white phosphorus reference
Common oxidation state	-3, +3, +5 common
Electronegativity	2.19

Structure & orbitals

White phosphorus consists of tetrahedral P₄ molecules packed in a molecular solid. Red and black phosphorus have different extended structures and are not represented by the same molecular model.

The 3s model is spherical and the 3p model uses the p angular form with selectable orientation. These are isolated-atom probability distributions, not pictures of bonds inside P₄ or extended black phosphorus.

Temperature / phase context

This slider uses white phosphorus as an explicit reference path: molecular solid below about 317.3 K, liquid to about 553.7 K, and gas above. Red and black phosphorus have different structures and transformations; the slider does not pretend all phosphorus allotropes share one phase path.

Five things to remember

- Atomic number 15 means every phosphorus nucleus contains 15 protons.
- Neutral phosphorus has the ground-state configuration [Ne] 3s² 3p³.
- ³¹P is the only stable natural phosphorus isotope.
- White phosphorus consists of P₄ molecules, while red and black phosphorus have different structures.
- Most phosphorus in nature occurs in phosphate compounds, not as free elemental phosphorus.

Phosphorus: Real World & Signature Science

Phosphorus in DNA, phosphate minerals and fertilizers is not elemental white phosphorus. The element's allotropes and its phosphate chemistry must be kept separate.

Why this element matters

Biology Phosphate groups are fundamental to DNA, RNA, ATP, membranes and mineralized tissues.	Fertilizers Phosphate rock is processed into fertilizer products that supply phosphorus as an essential plant nutrient.
Allotropes White, red and black phosphorus differ strongly in structure, reactivity and physical properties.	Safety distinction White phosphorus is highly reactive and hazardous; discussing its structure is not a handling guide.
Industrial chemistry Phosphorus compounds are used in fertilizers, food chemistry, materials and many specialized applications.	

From phosphate rock to phosphorus products: a high-level path

1. Phosphate rock is mined and beneficiated to concentrate phosphate minerals.
2. Most fertilizer pathways convert phosphate minerals into plant-available phosphate products rather than isolating elemental phosphorus.
3. Specialized industry can produce elemental phosphorus under controlled high-temperature conditions; operational details are outside this educational guide.
4. Use, recovery and nutrient management determine how efficiently phosphorus cycles through agriculture and society.

Where on Earth?

Phosphate rock - 2025 commodity context

Selected major phosphate-rock producers illustrate the geography of phosphorus feedstocks, not deposits of elemental phosphorus

Phosphorus cycle - Global conceptual

Phosphorus moves among rocks, soils, waters and living systems without a large atmospheric reservoir

Fertilizer chain - Conceptual

Phosphate rock is processed into phosphorus fertilizers and other compounds; elemental white phosphorus is a different material

History

1669 - Hennig Brand isolated phosphorus while searching for the philosopher's stone, making it one of the earliest elements discovered in modern-era chemistry.

19th century - Safer forms and better chemical understanding reduced reliance on hazardous white-phosphorus applications.

20th century - Industrial fertilizer production made phosphorus central to modern agriculture.

Today - Phosphorus remains essential to biology and food systems, while nutrient loss and recycling are major sustainability questions.

Uses

Fertilizers The largest phosphorus demand is tied to phosphate fertilizers for plant nutrition.	Biological molecules Phosphate chemistry is central to genetic material, energy transfer and membranes.
Specialty chemicals Phosphorus compounds are used in flame retardants, food chemistry, metal treatment and many other applications.	Materials research Different phosphorus allotropes, including black phosphorus, are studied for distinctive electronic and layered-material behavior.

Phosphorus: Isotopes, Questions & Evidence

Isotopes

³¹P - Stable - essentially 100% natural phosphorus

The teaching nucleus contains 15 protons and 16 neutrons.

³²P - Radioactive - tracer isotope

Used in regulated scientific and medical contexts; it is not part of ordinary natural abundance.

Phosphorus isotope identity - One stable natural isotope

The single stable isotope makes natural phosphorus isotope composition unusually simple.

Common questions

What is phosphorus's symbol?

Phosphorus has the symbol P.

Is phosphorus a metal or nonmetal?

Phosphorus is a nonmetal in Group 15.

How many valence electrons does phosphorus have?

Neutral phosphorus has five valence electrons, 3s²3p³.

How many neutrons does common phosphorus-31 have?

³¹P has 15 protons and 16 neutrons.

What is phosphorus used for?

Phosphate compounds are essential in fertilizers and biology, with additional industrial uses in materials and chemical products.

Are white and red phosphorus the same material?

They are allotropes of the same element but have different structures, reactivity and physical behavior.

Quick self-check

1. What is phosphorus's atomic number? Answer: 15

2. How many valence electrons does neutral phosphorus have? Answer: 5

3. Which is the only stable natural phosphorus isotope? Answer: ³¹P

4. What molecular unit is characteristic of white phosphorus? Answer: P₄ tetrahedra

5. Which statement is correct? Answer: Phosphate in biology is chemically different from elemental white phosphorus

Evidence & provenance

Atomic/isotope values and the white-phosphorus reference data are measured/evaluated. The P₄ viewer represents one white-phosphorus molecule, not every allotrope. Commodity geography refers to phosphate rock, not to free elemental phosphorus.

Core sources

Royal Society of Chemistry - Phosphorus	https://periodic-table.rsc.org/element/15/phosphorus
NIST - Atomic Data for Phosphorus	https://physics.nist.gov/PhysRefData/Handbook/Tables/phosphorustable1.htm
USGS - Mineral Commodity Summaries 2026	https://pubs.usgs.gov/publication/mcs2026