

Phosphorus

P

General Information

Discovery

Phosphorus was discovered in 1669 by H. Brandt in Hamburg, Germany, by extraction from urine.

Appearance

Phosphorus occurs in three major forms, white, red and black. The white form appears as a waxy white solid, but when pure is colourless and transparent. The red and black forms are powders of the appropriate colour.

Source

Phosphorus is not found free in nature, but is widely distributed in combination with minerals. An important source is phosphate rock, which contains the apatite minerals and is found in large quantities in the USA, the former USSR and elsewhere.

White phosphorus may be made commercially by several methods. Usually phosphate rock is heated in the presence of carbon and silica in a furnace, which produces phosphorus as a vapour which is then collected under water. It can then be converted to red phosphorus by heating for several days.

Uses

Fertilisers contain a high proportion of phosphorus and are manufactured from concentrated phosphoric acids. World wide demand for fertilisers has greatly increased in recent years as their importance to agriculture and farming has grown. Phosphorus is also important in the production of steel.

Phosphates are ingredients of some detergents, but are increasingly being omitted nowadays due to concern that high phosphate levels in natural water supplies cause the growth of undesirable algae. Phosphates are also used in the production of special glasses and fine chinaware.

Biological Role

Phosphorus is the basis of life as part of the DNA molecule. White phosphorus is very toxic and contact with skin can cause severe burns.

General Information

White phosphorus is insoluble in water but soluble in carbon disulphide. It burns spontaneously in air. When exposed to sunlight or heated in its own vapour to 250K it is converted to red phosphorus, which is less dangerous than the white form and does not ignite spontaneously. Red phosphorus is used in the manufacture of safety matches, pesticides, incendiary shells, smoke bombs and tracer pellets.

Physical Information

Atomic Number	15
Relative Atomic Mass ($^{12}\text{C}=12.000$)	30.974
Melting Point/K	317.3 (white), 683 (red)
Boiling Point/K	553 (white)
Density/kg m ⁻³ :	1820 (white) 2200 (red) 2690 (black), all at 293K
Ground State Electron Configuration	[Ne]3s ² 3p ³
Electron Affinity (M-M ⁻)/kJ mol ⁻¹	60

Key Isotopes

Nuclide	³¹ P	³² P	³³ P
Atomic mass	30.974	31.974	32.972
Natural abundance	100%	0%	0%
Half-life	stable	14.3 days	25 days

Ionisation Energies/kJ mol⁻¹

M - M ⁺	1011.7
M ⁺ - M ²⁺	1903.2
M ²⁺ - M ³⁺	2912
M ³⁺ - M ⁴⁺	4956
M ⁴⁺ - M ⁵⁺	6273
M ⁵⁺ - M ⁶⁺	21268
M ⁶⁺ - M ⁷⁺	25397
M ⁷⁺ - M ⁸⁺	29854
M ⁸⁺ - M ⁹⁺	35867
M ⁹⁺ - M ¹⁰⁺	40958

Other Information

Enthalpy of Fusion/kJ mol⁻¹ 2.51 (white)

Enthalpy of Vaporisation/kJ mol⁻¹ 51.9 (white)

Oxidation States

Main P^V

Others P^{-III}, P^{-II}, P^O, P^{II}, P^{III}

Covalent Bonds/kJ mol⁻¹

P - H 328

P - O 407

P = O 560

P - F 490

P - Cl 319

P - P 209