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An introduction to alkaloids and their applications in pharmaceutical chemistry

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Abstract

Alkaloids are a group of naturally occurring chemical compounds that contain mostly basic nitrogen atoms. This group also includes some related compounds with neutral and even weakly acidic properties. Some synthetic compounds of similar structure are also termed alkaloids. In addition to carbon, hydrogen and nitrogen, alkaloids may also contain oxygen, sulfur and, more rarely, other elements such as chlorine, bromine, and phosphorus. The properties and medicinal uses of alkaloids have been discussed.

Keywords: alkaloids, pharmaceutical chemistry, nitrogen atoms, bromine

1. Introduction

1.1 Properties

Most alkaloids contain oxygen in their molecular structure; those compounds are usually colorless crystals at ambient conditions. Oxygen-free alkaloids, such as nicotine or coniine, are typically volatile, colorless, oily liquid. Some alkaloids are colored, like berberine (yellow) and sanguinarine (orange). Most alkaloids are weak bases, but some, such as the bromine and theophylline, are amphoteric. Many alkaloids dissolve poorly in water but readily dissolve in organic solvents, such as diethyl ether, chloroform or 1, 2-dichloroethane. Caffeine, cocaine, codeine and nicotine are water-soluble (with a solubility of $\geq 1\text{g/L}$), whereas others, including morphine are highly water-soluble (0.1–1 g/L). Alkaloids and acids form salts of various strengths. These salts are usually soluble in water and ethanol and poorly soluble in most organic solvents.

1.2 Biological role

The role of alkaloids for living organisms that produce them is still unclear. It was initially assumed that the alkaloids are the final products of nitrogen metabolism in plants, as urea in mammals. It was later shown that alkaloid concentrations vary over time, and this hypothesis was refuted. Most of the known functions of alkaloids are related to protection.

However, some animals are adapted to alkaloids and even use them in their own metabolism. Such alkaloid-related substances as serotonin, dopamine and histamine are important neurotransmitters in animals. Alkaloids are also known to regulate plant growth. Another example of an organism that uses alkaloids for protection is the *Utetheisa ornatrix*, more commonly known as the ornate moth. Pyrrolizidine alkaloids render these larvae and adult moths unpalatable to many of their natural enemies like coccinellid beetles, green lacewings, insectivorous hemiptera and insectivorous bats.

1.3 Applications in medicine

Medical use of alkaloid-containing plants has a long history, and, thus, when the first alkaloids were isolated in the 19th century, they immediately found application in clinical practice. Many alkaloids are still used in medicine, usually in the form of salts, including the following:

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Alkaloid	Action
Ajmaline	antiarrhythmic
Atropine, scopolamine, hyoscyamine	anticholinergic
Caffeine	stimulant, adenosine receptor antagonist
Codeine	cough medicine, analgesic
Colchicine	remedy for gout
Emetine	antiprotozoal agent
Ergot alkaloids	sympathomimetic, vasodilator, antihypertensive
Morphine	analgesic
Nicotine	stimulant, nicotinic acetylcholine receptor agonist
Physostigmine	inhibitor of acetylcholinesterase
Quinidine	antiarrhythmic
Quinine	antipyretics, antimalarial
Reserpine	antihypertensive
Tubocurarine	muscle relaxant
Vinblastine, vincristine	antitumor
Vincamine	vasodilating, antihypertensive
Yohimbine	stimulant, aphrodisiac

Many synthetic and semisynthetic drugs are structural modifications of the alkaloids, which were designed to enhance or change the primary effect of the drug and reduce unwanted side-effects. For example, naloxone, an opioid receptor antagonist, is a derivative of the baine that is present in opium.

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