Fluorescent/luminescent detection of natural amino acids by organometallic systems

Jing Wang, Hai-Bo Liu, Zhangfa Tong, Chang-Sik Ha

School of Chemistry and Chemical Engineering, Guangxi University, Nanning, Guangxi 530004, People’s Republic of China
Department of Polymer Science and Engineering, Pusan National University, Busan 609-735, Republic of Korea

Abstract: AAs, amino acids; CSH, glutathione; NPs, nanoparticles; Tpy, terpyridine; Trp, tryptophan; His, histidine; Ala, alanine; Asp, aspartic acid; Cys, cysteine; ICT, intramolecular charge-transfer; THF, tetrahydrofuran; PBS, phosphate-buffered saline; PET, photoinduced electron transfer; MLCT, metal-to-ligand charge transfer; DMSO, dimethyl sulfoxide; rGO, reduced graphene oxide; acac, acetylacetonate; FRET, fluorescence resonance energy transfer; PL, photoluminescence; DNBS, 2,4-dinitrobenzenesulfonfonyl; NIR, near infrared; ssDNA, single-stranded DNA; C, cytosine; QDs, quantum dots; BSA, bovine serum albumin; IDA, indicator-displacement assay; Tyr, tyrosine; MPA, mercapto propionic acid; GNRs, gold nanorods; Met, methionine; Gly, glycine; MeOH, methanol; HEPES, 4-(2-hydroxyethyl)-1-piperazineethanesulfonic acid; Hcy, homocysteine; ET, electron transfer; Ncs, nanoclusters; Phen, 1,10-phenanthroline; Phe, phenylalanine; Val, valine; Pro, proline; Gln, glutamic acid; Arg, arginine; LOD, limit of detection; LMCT, ligand-to-metal charge transfer; DMF, dimethylformamide; BINOL, 1,1’-binaphthol; IFE, fluorescence inner filter effect; T, thymine; pba, 4-(2-pyridyl)benzaldehyde; bppy, 2,2’-bipyridine; Ser, serine; ECL, electrochemiluminescence; G, guanine; NEM, N-ethylmaleimide; dsDNA, double-stranded DNA; Cit, sodium citrate; MAA, mercaptocacetic acid; HSA, human serum albumin; Thr, threonine; DA, dopamine; Leu, leucine; Asn, asparagine; Ile, isoleucine; Lys, lysine; Gln, glutamin.
1. Introduction

Amino acids (AAs) are important components in a range of chemical and biological systems. They combine to yield proteins, enzymes, structural elements and many other molecules with biological activity. Their role as building blocks in living systems, along with the discovery that the concentration of free AAs is closely related to the metabolism of peptides and proteins in life and various physiological processes, has prompted increasing interest in their detection in various fields, such as chemistry, biochemistry and clinical chemistry [1–4]. In view of the role played by the 20 natural AAs in daily life [5–17], the development of techniques for sensing and monitoring natural AAs is important in the diagnosis and treatment of diseases.

Among the different methods applied to the detection of AAs, fluorescence/luminescence spectrscopic techniques, have drawn substantial interest from researchers owing to their advantageous features including simplicity, low cost, high sensitivity, quick response time, easy sample preparation, noninvasive and nondestructive nature, etc. Due to the important roles played by 20 natural amino acids in living systems, this review focuses on recent contributions (from the year 2000 until July 2014) regarding the development of fluorescent/luminescent chemosensors and chemodosimeters to detect specific AAs, as well as chiral recognition to discriminate AA enantiomers (i.e., d and l), and pattern recognition to distinguish a range of AAs simultaneously based on fluorescent/luminescent organometallic systems, which include organic–metal complexes and hybrid organic–metal nanoparticles/nanoclusters.

2. Detection mechanisms

2.1. Binding site-signaling subunit approach

In the binding site-signaling subunits approach [23–25], the “binding site” part (receptor) and “signaling subunit” part (indicator) are linked through a covalent bond, and the interaction of the analytes (such as AAs) with the binding site alters the electronic properties of the signaling subunit, resulting in sensing of the target analytes via color, absorption or emission modulation. The binding between the receptor and analyte is typically labile and reversible, and involves different interactions, including electronic interactions, hydrogen bonding and metal-ligand interactions, etc.

2.2. Displacement approach

The displacement approach [26] uses binding sites and signaling subunits to form a molecular ensemble through non-covalent interactions. Upon the addition of a specific amino acid (AA), the indicators are replaced, resulting in a change in their optical properties. This type of supramolecular approach toward sensing is very simple to implement. Furthermore, the sensitivity and selectivity of the assay can be modulated by varying the receptor-indicator ratio or sensing conditions (e.g. pH).

2.3. Chemosimeter approach

Chemosimeters [27] are molecular devices that interact with their analytes and yield physically measurable signals in an irreversible manner. Conventional chemodosimeters are generally molecular assemblies of receptor and signaling units. In contrast to chemosensors, which respond to the real-time concentration of their analytes, chemodosimeters respond to their analytes in a cumulative manner. Compared with chemosensors, chemodosimeters have advantages in terms of selectivity and sensitivity, and their cumulative effect plays an important role in the detection of analytes [28].

3. The advantages of metal and organic combination

For detecting AAs, metal ions can play an important role [29]; (1) they can represent the active site for interacting with AAs [30]. They serve as binding sites in the development of AA probes. An obvious requirement for an organic-metal combined system to serve as a binding site is its stability. (2) The interaction between a metal center and AAs is often a convenient route for achieving strong binding [26]. In this case, AAs can capture metals from organometallic systems and the organic part can be displaced by the AAs. (3) Metal ions can also be used profitably as structural elements for assisting AAs binding without exerting any a direct interaction with AAs [31,32].