k is 0, 1, 2, 3, or 4;

each n is independently 0 or 1; and

each p is independently 0, 1, 2, or 3.

In another aspect, there is provided a zwitterion of the compound as disclosed herein.

In another aspect, there is provided a pharmaceutical composition which comprises a compound as defined herein, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier.

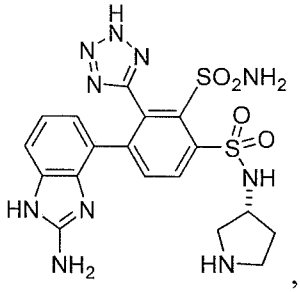
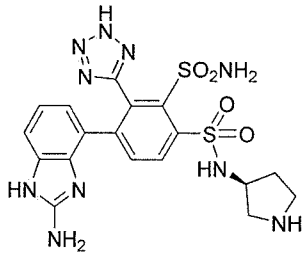
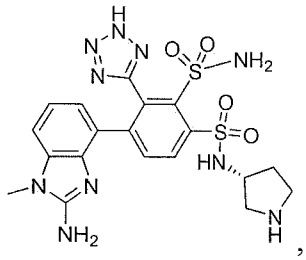
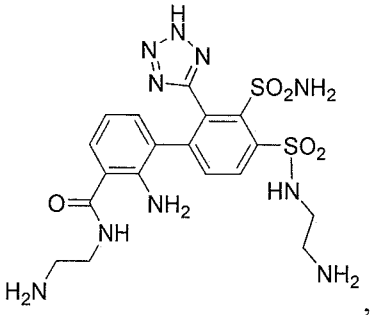
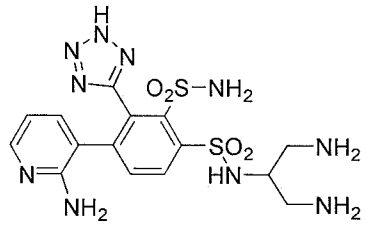
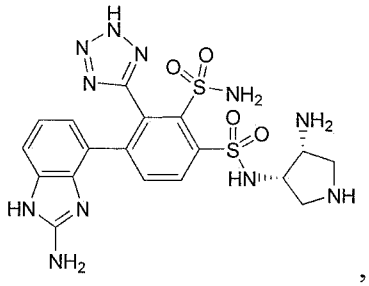
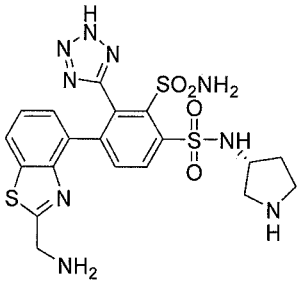
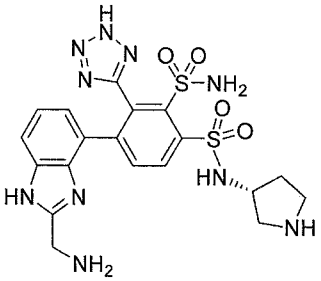
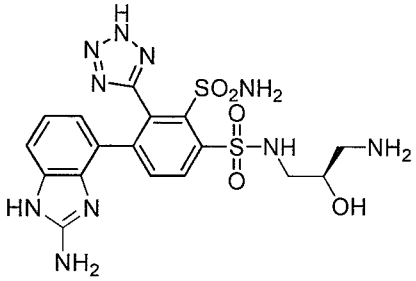
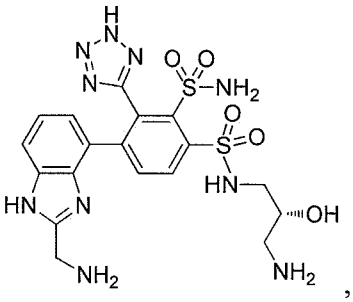
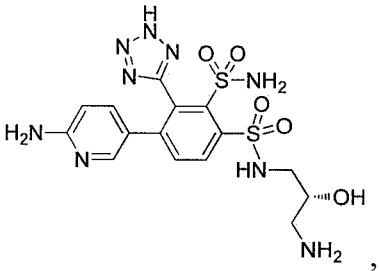
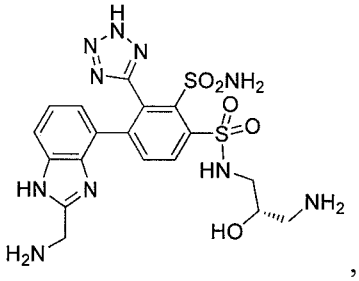
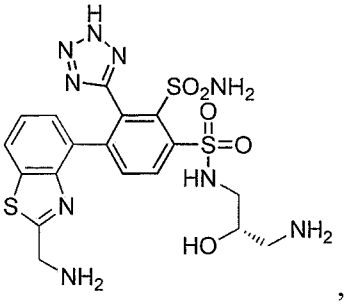
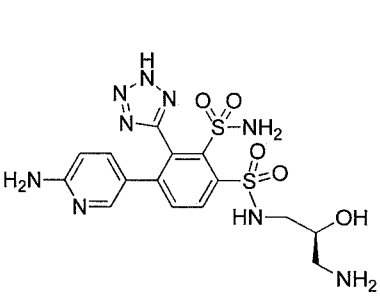
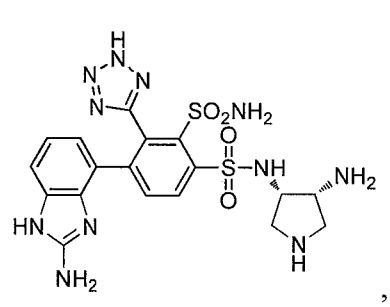
Compounds of Formula I inhibit metallo-β lactamases and can synergize the antibacterial effects of β lactam antibiotics (*e.g.*, imipenem, ceftazidime, ceftolozane, and piperacillin) against microorganisms normally resistant to β lactam antibiotics as a result of the presence of the metallo-β lactamases. Compounds of the present disclosure are effective against metallo-β lactamases and their combination with a β-lactam antibiotic, such as imipenem, ceftazidime, ceftolozane, or piperacillin, can provide effective treatment of bacterial infections caused by metallo-β lactamase-producing microorganisms. Accordingly, in certain embodiments, the present disclosure provides compositions comprising a compound of Formula I, IA, or IB with a β-lactam antibiotic, and optionally one or more additional β-lactamase inhibitors, suitable for use against metallo-β lactamase producing bacteria such as *Pseudomonas spp.* and *Klebsiella spp.* In some embodiments, the additional one or more β-lactamase inhibitor(s) is a serine (Class A, C and D) β-lactamase inhibitor. The disclosure also includes compositions comprising a compound of Formula I, IA, or IB or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier. The disclosure further includes methods for treating bacterial infections and inhibiting bacterial growth by administration of a compound of Formula I, IA, or IB, or a pharmaceutically acceptable salt thereof, to a patient in need thereof, or by administration of a pharmaceutical composition comprising a compound of Formula I, IA, or IB or its salt and a pharmaceutically acceptable carrier.

In another aspect, there is provided a (i) compound as defined herein, or a pharmaceutically acceptable salt thereof, optionally in combination with a beta-lactam antibiotic or (ii) pharmaceutical composition as defined herein for use as a medicament.

In another aspect, there is provided use of a compound as defined herein, or a pharmaceutically acceptable salt thereof, and a beta-lactam antibiotic in the manufacture of a medicament for combination therapy of a bacterial infection.

In another aspect, there is provided use of a pharmaceutical composition as defined herein in the manufacture of a medicament for treating a bacterial infection.

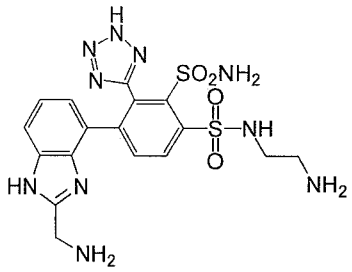
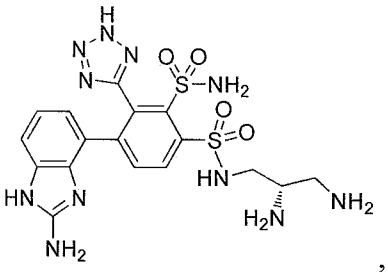
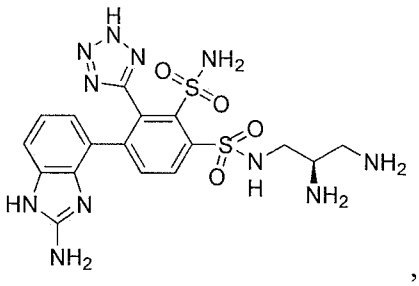
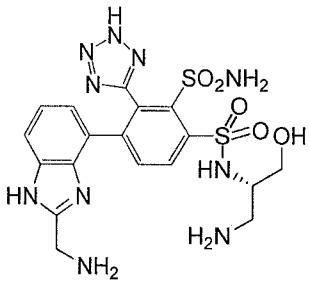
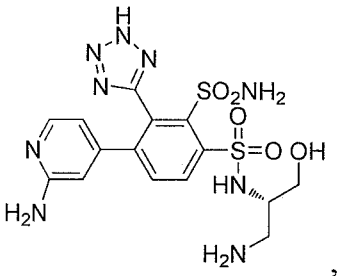
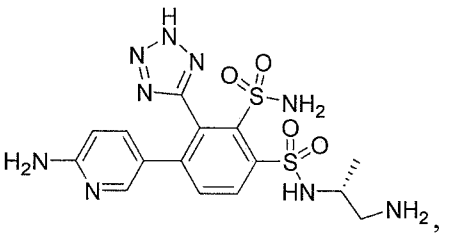
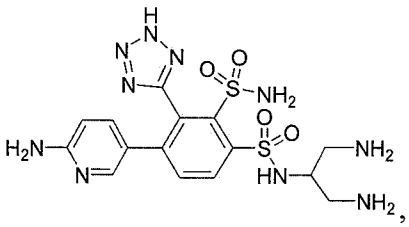
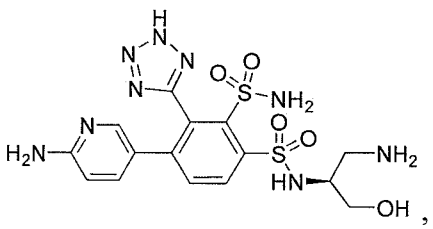
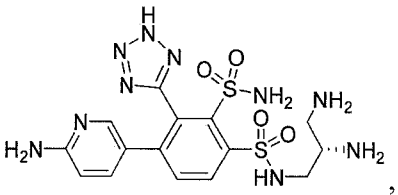
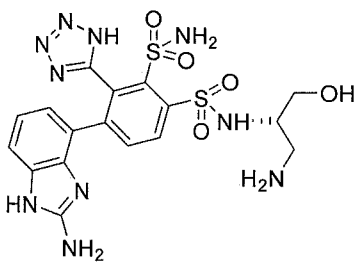
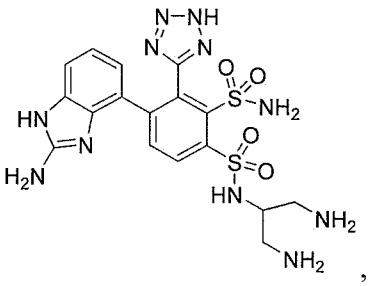
10. A compound of claim 1 having the structure


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, or

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or a pharmaceutically acceptable salt thereof.

11. A zwitterion of the compound of claim 10.

12. A pharmaceutical composition which comprises a compound acccording to any one of claims 1 to 11, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier.

13. A pharmaceutical composition according to claim 12, which further comprises an effective amount of a beta-lactam antibiotic.

14. The pharmaceutical composition according to claim 12 or 13, which further comprises an effective amount of one or more beta-lactamase inhibitor compounds.

15. The pharmaceutical composition according to claim 14, wherein the composition comprises a beta-lactamase inhibitor compound selected from the group consisting of: relebactam, avibactam, vaborbactam, tazobactam, sulbactam, and clavulanic acid.

16. The pharmaceutical composition according to claim 15, wherein the beta-lactamase inhibitor compound is tazobactam and the beta-lactam antibiotic is ceftolozane.

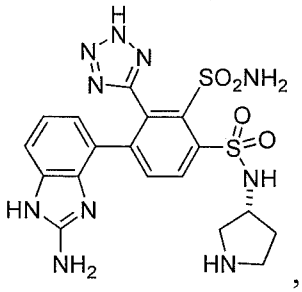
17. The pharmaceutical composition according to claim 15, wherein the beta-lactamase inhibitor compound is relebactam.

18. The pharmaceutical composition according to any of claims 13 -16, wherein the beta-lactam antibiotic is selected from the group consisting of imipenem, ertapenem, meropenem, doripenem, biapenem, panipenem, ticarcillin, ampicillin, amoxicillin, carbenicillin, piperacillin, azlocillin, mezlocillin, cefoperazone, cefotaxime, ceftriaxone, cefipime, ceftolozane, and ceftazidime.

19. The pharmaceutical composition according to any of claims 13-15 and 17-18, wherein the beta-lactam antibiotic is imipenem.

20. The pharmaceutical composition according to claim 19, further comprising cilastatin or a pharmaceutically acceptable salt thereof.

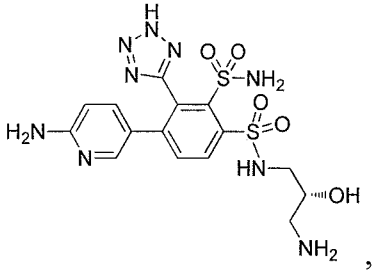
21. The compound of claim 1, having the structure



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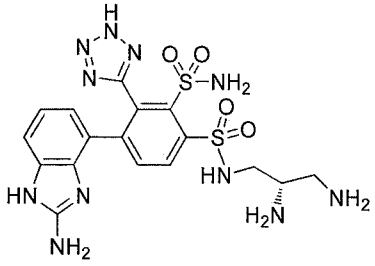
or a pharmaceutically acceptable salt thereof.

22. The compound of claim 1, having the structure



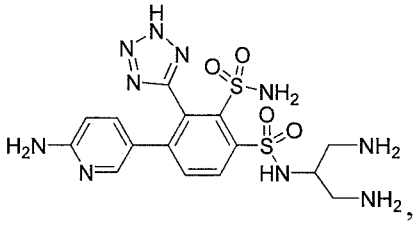
or a pharmaceutically acceptable salt thereof.

23. The compound of claim 1, having the structure



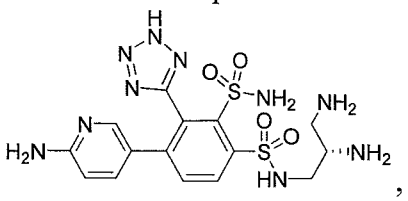
or a pharmaceutically acceptable salt thereof.

24. The compound of claim 1, having the structure



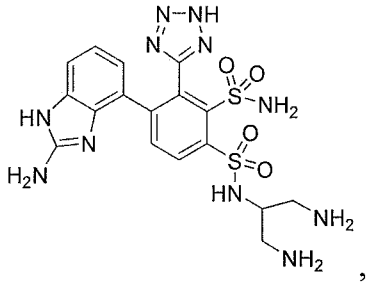
or a pharmaceutically acceptable salt thereof.

25. The compound of claim 1, having the structure



or a pharmaceutically acceptable salt thereof.

26. The compound of claim 1, having the structure



or a pharmaceutically acceptable salt thereof.

27. A pharmaceutical composition which comprises a compound according to any one of claims 21 to 26, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier.

28. A (i) compound according to any one of claims 1 to 11 or 21 to 26, or a pharmaceutically acceptable salt thereof, optionally in combination with a beta-lactam antibiotic or (ii) pharmaceutical composition according to any one of claims 12 to 20 or 27 for use as a medicament.

29. Use of a compound according to any one of claims 1 to 11 or 21 to 26, or a pharmaceutically acceptable salt thereof, and a beta-lactam antibiotic in the manufacture of a medicament for combination therapy of a bacterial infection.

30. Use of a pharmaceutical composition according to any one of claims 13 to 20 in the manufacture of a medicament for treating a bacterial infection.

31. The compound or pharmaceutical composition for use of claim 28 or the use of any one of claims 29 to 30, wherein the beta-lactam antibiotic is selected from the group consisting of imipenem, ertapenem, meropenem, doripenem, biapenem, panipenem, ticarcillin, ampicillin, amoxicillin, carbenicillin, piperacillin, azlocillin, mezlocillin, cefoperazone, cefotaxime, ceftriaxone, cefipime, ceftolozane, and ceftazidime.

32. The compound or pharmaceutical composition for use of claim 28 or the use of any one of claims 29 to 30, wherein the beta-lactam antibiotic is imipenem.

33. Use of a compound according to any one of claims 1 to 11 or 21 to 26, or a pharmaceutically acceptable salt thereof, and a therapeutically effective amount of imipenem, cilastatin, and relebactam in the manufacture of a medicament for the treatment of a bacterial infection.

34. The use of any one of claims 29 to 33, wherein the bacterial infection is due to *Pseudomonas spp.*, *Klebsiella spp.*, *Enterobacter spp.*, *Escherichi spp.*, *Morganella spp.*, *Citrobacter spp.*, *Serratia, spp. or Acintetobacter spp.*