Initial productions:

1. S->bA

2. S->BC

3. A->a

4. A->aS

5. A->bCaCa

6. B->A

7. B->bS

8. B->bCAa

9. C->-

10. C->AB

11. D->AB

Eliminating epsilon productions

|  |  |
| --- | --- |
| 1. S->bA  2. S->BC  3. A->a  4. A->aS  5. A→bCaCa  6. B->A  7. B->bS  8. B->bCAa  9. C->-  10. C->AB  11. D->AB | S → B  A->baCa  A->baa  A→bCaa  B->bAa |

Epsilon-free productions:

1. S->bA

2. S->BC

3. S->B

4. A->a

5. A->aS

6. A->bCaCa

7. A->baCa

8. A->baa

9. A->bCaa

10. B->A

11. B->bS

12. B->bCAa

13. B->bAa

14. C->AB

15. D->AB

Eliminating the renaming

|  |  |
| --- | --- |
| 1. S->bA  2. S->BC  3. S->B  4. A->a  5. A->aS  6. A->bCaCa  7. A->baCa  8. A->baa  9. A->bCaa  10. B->A  11. B->bS  12. B->bCAa  13. B->bAa  14. C->AB  15. D->AB | B->a  B->aS  B->bCaCa  B->baCa  B->baa  B->bCaa |

|  |  |
| --- | --- |
| 1. S->bA  2. S->BC  3. S->B  4. A->a  5. A->aS  6. A->bCaCa  7. A->baCa  8. A->baa  9. A->bCaa  11. B->bS  12. B->bCAa  13. B→bAa  15. B->a  16. B->aS  17. B->bCaCa  18. B->baCa  19. B->baa  20. B->bCaa  14. C->AB  15. D->AB | S->bS  S->bCAa  S->bAa  S->a  S->aS  S->bCaCa  S->baCa  S->baa  S->bCaa |

Renaming-free productions:

1. S->bA

2. S->BC

3. S->bS

4. S->bCAa

5. S->bAa

6. S->a

7. S->aS

8. S->bCaCa

9. S->baCa

10. S->baa

11. S->bCaa

12. B->bS

13. B->bCAa

14. B->bAa

15. B->a

16. B->aS

17. B->bCaCa

18. B->baCa

19. B->baa

20. B->bCaa

21. A->a

22. A->aS

23. A->bCaCa

24. A->baCa

25. A->baa

26. A->bCaa

27. C->AB

28. D->AB

Eliminating unproductive symbols

|  |  |
| --- | --- |
| 1. S->bA  2. S->BC  3. S->bS  4. S->bCAa  5. S->bAa  6. S->a  7. S->aS  8. S->bCaCa  9. S->baCa  10. S->baa  11. S->bCaa  12. B->bS  13. B->bCAa  14. B->bAa  15. B->a  16. B->aS  17. B->bCaCa  18. B->baCa  19. B->baa  20. B->bCaa  21. A->a  22. A->aS  23. A->bCaCa  24. A->baCa  25. A->baa  26. A->bCaa  27. C->AB  28. D->AB |  |

There are no unproductive symbols. Result:

1. S->bA

2. S->BC

3. S->bS

4. S->bCAa

5. S->bAa

6. S->a

7. S->aS

8. S->bCaCa

9. S->baCa

10. S->baa

11. S->bCaa

12. B->bS

13. B->bCAa

14. B->bAa

15. B->a

16. B->aS

17. B->bCaCa

18. B->baCa

19. B->baa

20. B->bCaa

21. A->a

22. A->aS

23. A->bCaCa

24. A->baCa

25. A->baa

26. A->bCaa

27. C->AB

28. D->AB

Eliminating inaccessible productions

|  |  |
| --- | --- |
| 1. S->bA  2. S->BC  3. S->bS  4. S->bCAa  5. S->bAa  6. S->a  7. S->aS  8. S->bCaCa  9. S->baCa  10. S->baa  11. S->bCaa  12. B->bS  13. B->bCAa  14. B->bAa  15. B->a  16. B->aS  17. B->bCaCa  18. B->baCa  19. B->baa  20. B->bCaa  21. A->a  22. A->aS  23. A->bCaCa  24. A->baCa  25. A->baa  26. A->bCaa  27. C→AB  28. D->AB |  |

Inaccessible productions eliminated:

1. S->bA

2. S->BC

3. S->bS

4. S->bCAa

5. S->bAa

6. S->a

7. S->aS

8. S->bCaCa

9. S->baCa

10. S->baa

11. S->bCaa

12. B->bS

13. B->bCAa

14. B->bAa

15. B->a

16. B->aS

17. B->bCaCa

18. B->baCa

19. B->baa

20. B->bCaa

21. A->a

22. A->aS

23. A->bCaCa

24. A->baCa

25. A->baa

26. A->bCaa

27. C->AB

Following the CNF rules:

|  |  |  |  |
| --- | --- | --- | --- |
| 1. S->bA  2. S->BC  3. S->bS  4. S->bCAa  5. S->bAa  6. S->a  7. S->aS  8. S->bCaCa  9. S->baCa  10. S->baa  11. S->bCaa  12. B->bS  13. B->bCAa  14. B->bAa  15. B->a  16. B->aS  17. B->bCaCa  18. B->baCa  19. B->baa  20. B->bCaa  21. A->a  22. A->aS  23. A->bCaCa  24. A->baCa  25. A->baa  26. A->bCaa  27. C->AB | S→X1 A  S→B C  S→X1 S  S→b Y0 a  S→X1 A X0  S→a  S→X0 S  S→X1 C X0 C X0  S→X1 X0 C X0  S→X1 X0 X0  S→X1 C X0 X0  B→X1 S  B→X1 Y0 X0  B→X1 A X0  B→a  B→X0 S  B→X1 C X0 C X0  B→X1 X0 C X0  B→X1 X0 X0  B→X1 C X0 X0  A→a  A→X0 S  A→X1 C X0 C X0  A→X1 X0 C X0  A→X1 X0 X0  A→X1 C X0 X0  C->AB | S→X1 Y0 X0  S→Z2 X0  S→Z3 Z4 X0  S→Z5 Z6  S→Z5 X0  S→Z3 Z7  B→ Z1 X0  B→Z2 X0  B→Z3 Z4 X0  B→Z5 Z6  B→Z5 X0  B→Z3 Z7  A→Z3 Z4 X0  A→Z5 Z6  A→Z5 X0  A→Z3 Z7 | S→Z1 X0  S→Z8 X0  B→Z8 X0  A->Z8X0 |

Additionally made productions:

|  |  |  |
| --- | --- | --- |
| From terminals | From initial non-terminals | Others |
| 28. X0->a  29. X1->b | 30. Y0->CA | 31. Z1->X1Y0  32. Z2->X1A  33. Z3->X1C  34. Z4->X0C  35. Z5->X1X0  36. Z6->CX0  37. Z7->X0X0  38. Z8->Z3Z4 |

CNF:

1. S->BC

2. S->a

3. S->X1A

4. S->X1S

5. S->X0S

6. S->Z1X0

7. S->Z2X0

8. S->Z8X0

9. S->Z5Z6

10. S->Z5X0

11. S->Z3Z7

12. B->a

13. B->X1S

14. B->X0S

15. B->Z1X0

16. B->Z2X0

17. B->Z8X0

18. B->Z5Z6

19. B->Z5X0

20. B->Z3Z7

21. A->a

22. A->X0S

23. A->Z8X0

24. A->Z5Z6

25. A->Z5X0

26. A->Z3Z7

27. C->AB

28. X0->a

29. X1->b

30. Y0->CA

31. Z1->X1Y0

32. Z2->X1A

33. Z3->X1C

34. Z4->X0C

35. Z5->X1X0

36. Z6->CX0

37. Z7->X0X0

38. Z8->Z3Z4