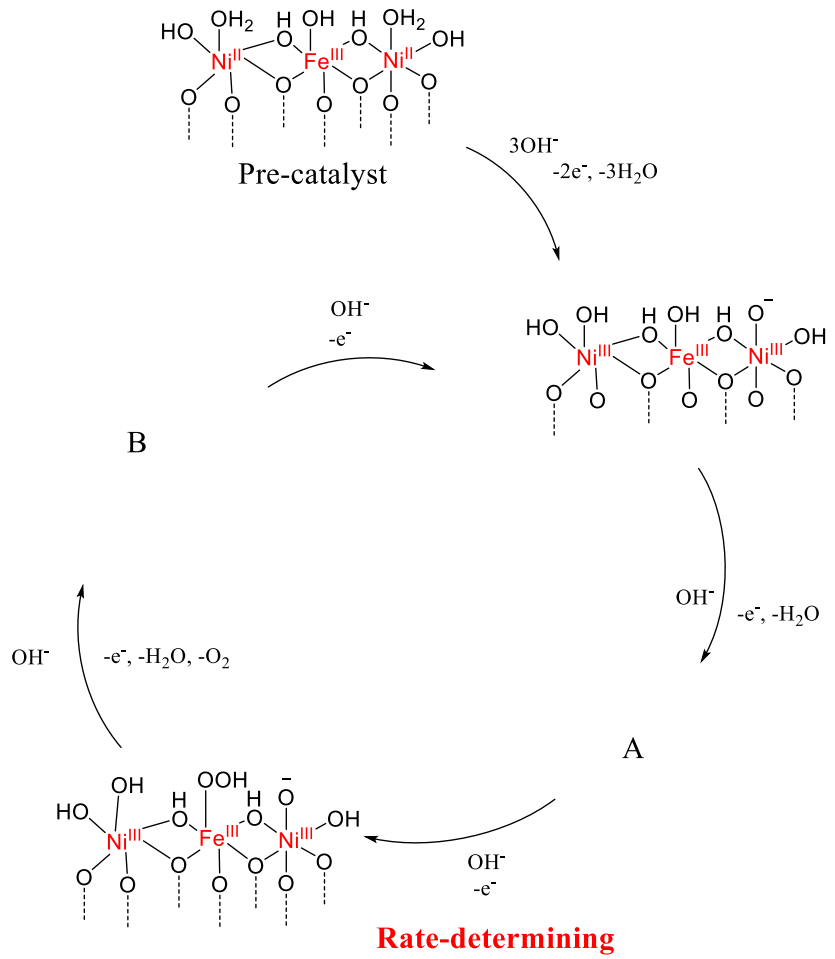
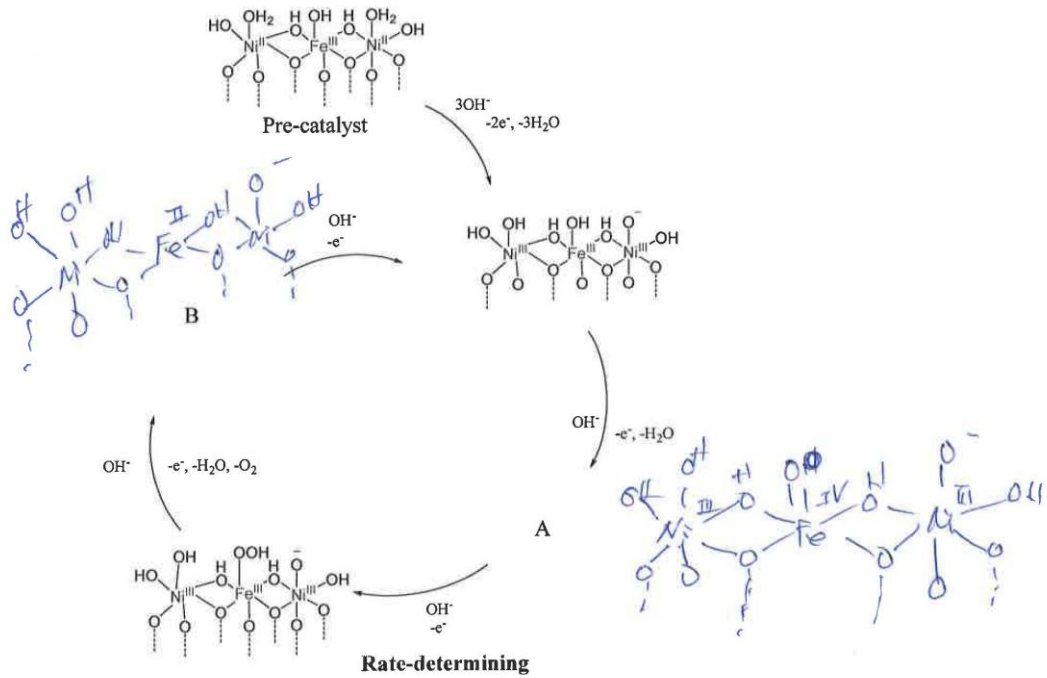
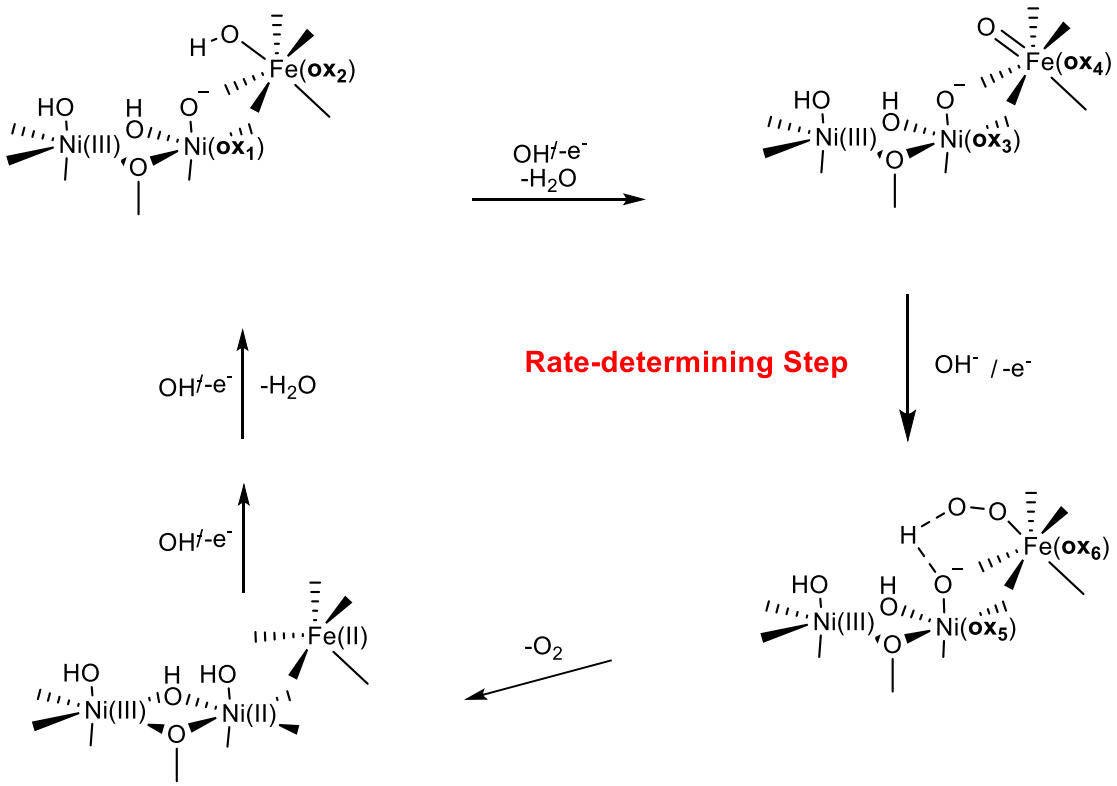
Nickel iron oxide (NiFeOx) is a benchmark catalyst for the oxygen evolution reaction. The following mechanism is proposed for NiFeOx. Please complete the missing species (A and B) in the catalytic cycle. Label the oxidation states of Ni and Fe.




Pre-catalyst
3OH⁻
-2e⁻, -3H₂O
OH⁻
-e⁻
B
OH⁻
-e⁻, -H₂O
A
OH⁻
-e⁻, -H₂O, -O₂
OH⁻
-e⁻
Rate-determining

A novel catalyst, FeOOH-NiOOH, exhibits about 10-fold higher intrinsic activity than $NiFeO_x$. The following mechanism has been proposed. Please complete the missing oxidation states of Ni and Fe (ox1-ox6).



$OX_1 =$ III

$OX_2 =$ III

$OX_3 =$ II

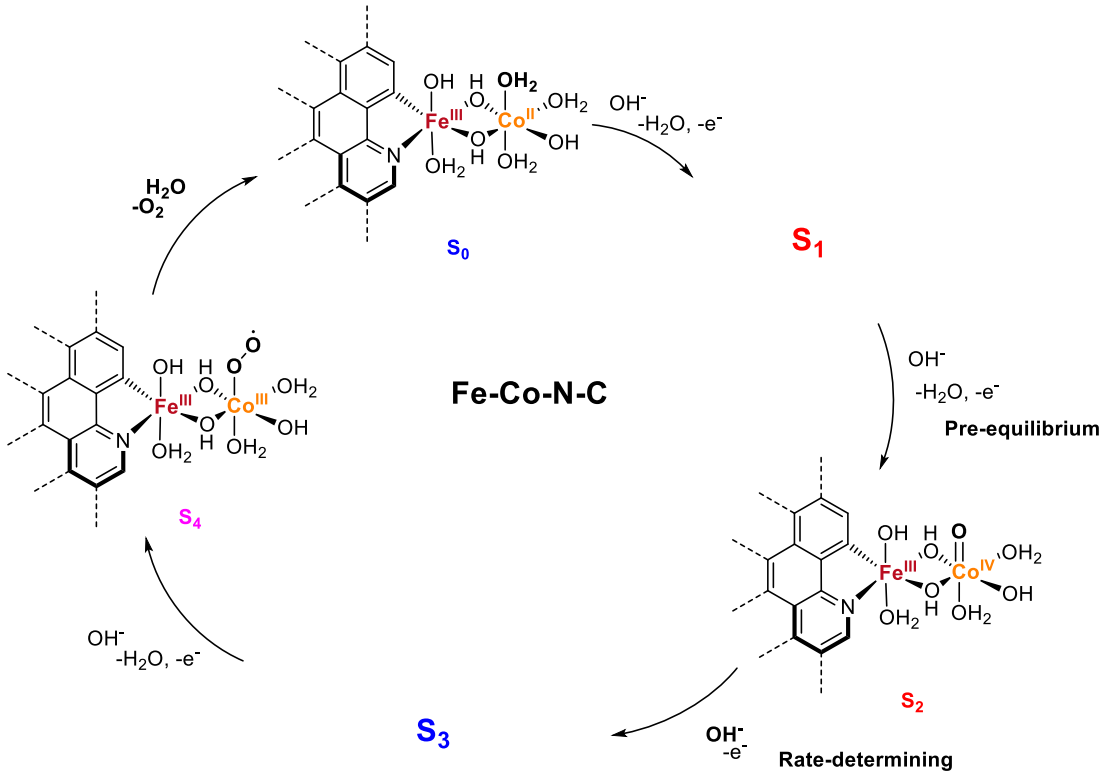
$OX_4 =$ IV

$OX_5 =$ III

$OX_6 =$ III

eac

M-N-C compounds have emerged as a new class of electrocatalysts. They behave like heterogeneous catalysts but have active sites similar to molecular catalysts. A Fe-Co-N-C catalyst (see figure below) was recently reported for the oxygen evolution reaction. The following mechanism has been proposed for the reaction. In this type of mechanism, a pre-equilibrium followed by a rate determining step is generally assumed. The rate determining step is from S2 to S3.



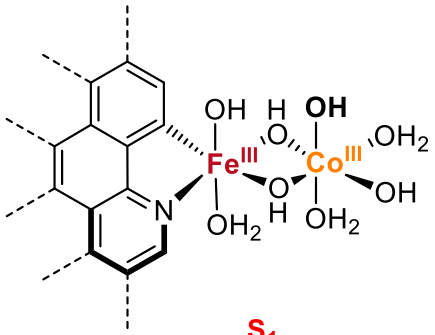
(i) According to this mechanism, which metal is the active site?

(ii) Please draw the structure of intermediates S_1 and S_3. Label the oxidation states of Fe and Co.

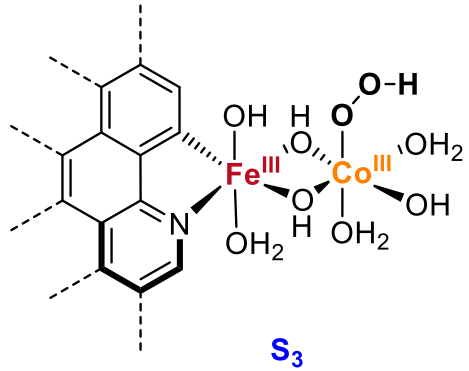
(iii) Among the five species S0-S4, which species might be detected during OER catalysis?

(i): Co

(ii):



S_1



S_3

(iii) S1 and S2;