19.2: Oxidation-Reductions Reactions

Balancing Redox Reactions in Acidic Solution

19.2.1. Balance the reaction in an acidic solution:

$$Cu(s)\ +\ NO_3^-(aq)\ \rightarrow\ Cu^{2+}(aq)\ +\ NO_2(g)$$

19.2.2. Balance the reaction in an acidic solution:

$$Mn^{2+}(aq) + BiO_3^-(aq) \rightarrow Bi^{3+}(aq) + MnO_4^-(aq)$$

19.2.3. Balance the reaction in an acidic solution:

$$Cr_2O_7^{2-}(aq) + Cl^-(aq) \rightarrow Cr^{3+}(aq) + ClO_3^-(aq)$$

19.2.4. Balance the reaction in an acidic solution:

$$IO_3^-(aq) + HNO_2(aq) \rightarrow I^-(aq) + NO_3^-(aq)$$

19.2.5. Balance the reaction in an acidic solution:

$$Fe_2S(s) + Ce^{4+}(aq) \rightarrow Fe^{2+}(aq) + SO_4^{2-}(aq) + Ce^{3+}(aq)$$

Balancing Redox Reactions in Basic Solutions

19.2.6. Balance the reactions in the basic solution:

$$Fe(s) + NO_3^-(aq) \rightarrow FeO_2^{2-}(aq) + NH_3(aq)$$

19.2.7. Balance the reactions in the basic solution:

$$Cr(OH)_3(s) + BrO^-(aq) \rightarrow CrO_4^{2-}(aq) + Br_2(l)$$

19.2.8. Balance the reactions in the basic solution:

$$Pb(OH)_4^{2-}(aq) + ClO^-(aq) \rightarrow PbO_2(s) + Cl^-(aq)$$

19.2.9. Balance the reactions in the basic solution:

$$Cl^-(aq) + MnO_4^-(aq) \rightarrow Cl_2(g) + MnO_2(s)$$

19.2.10. Balance the reactions in the basic solution:

$$IO_3^-(aq) + NO_2^-(aq) \rightarrow I^-(aq) + NO_3^-(aq)$$

19.3: Electrochemical Cells

Electrochemical Cell Notation

19.3.1. Write the following reactions in standard electrochemical cell notation at standard state conditions.

a. $Cu(s) + Cd^{2+}(aq) \rightarrow Cu^{2+}(aq) + Cd(s)$

b. $2Na(s) + Fe^{2+}(aq) \rightarrow 2Na^+(aq) + Fe(s)$

c. $3Zn(s) + 2Fe^{3+}(aq) \rightarrow 3Zn^{2+}(aq) + 2Fe(s)$

d. $2Al(s) + 3Mn^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Mn(s)$

e. $2H^+(aq) + Zn(s) \rightarrow H_2(g) + Zn^{2+}(aq)$

f. $Hg(l) + Sn^{4+}(aq) \rightarrow {Hg_2}^{2+} + Sn(s)$

Voltaic Cell

19.3.2. What is the half-reaction at the anode in the voltaic reaction?

$$2Cu^+(aq) + I_2(l) \rightarrow 2Cu^{2+}(aq) + 2I^-(aq)$$

19.3.3. What is the reaction occurring at the cathode from Question 19.3.2?

19.3.4. Which one can occur at the cathode of an electrochemical cell?

a. $NO \rightarrow NO_3^-$
b. $Cr_2O_7^{2-} \rightarrow Cr^{7+}$
c. $I_2 \rightarrow I^-$
d. none of the above

19.3.5. Which one can occur at the anode of an electrochemical cell?

a. $Cr_2O_7^{2-} \rightarrow Cr^{7+}$
b. $Fe^{2+} \rightarrow Fe$
c. $I_2 \rightarrow I^-$
d. none of the above

19.3.6. Using the information given, determine which reaction occurs at the anode.

i. $Al(s) \rightarrow Al^{3+}(aq) + 3e^-$
ii. $ClO_3^-(aq) + 6H^+(aq) + 6e^- \rightarrow Cl^-(aq) + 3H_2O(l)$

a. a
b. b
c. neither
d. both

19.3.7. Using the same information in Question 19.3.6, which electrode is consumed?

a. anode
b. cathode
c. neither
d. both

19.3.8. Using the same information in Question 19.3.6, which electrode is positive?

a. anode
b. cathode
c. both
d. neither

19.4: Electrochemical Cell Fundamentals

Figure 19.1: Use the following information to answer Questions 19.4.1-19.4.5

Half-reaction	ϵ_{red}^0
$I_2(s) + 2e^- \rightarrow 2I^-(aq)$	0.54 V
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	-0.44 V
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	0.77 V
$Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$	-0.74 V

19.4.1. Determine the standard potential (V) for the cell reaction.

$$2I^-(aq) + 2Fe^{3+}(aq) \rightarrow 2Fe^{2+}(aq) + I_2(s)$$

19.4.2. Determine the standard potential (V) for the cell reaction.

$$Cr(s) + 3Fe^{3+}(aq) \rightarrow 3Fe^{2+}(aq) + Cr^{3+}(aq)$$

19.4.3. Determine the standard potential (V) for the cell reaction.

$$Fe(s) + 2Fe^{3+}(aq) \rightarrow 3Fe^{2+}(aq)$$

19.4.4. Determine the standard potential (V) for the cell reaction.

$$2Cr(s) + 3Fe^{2+}(aq) \rightarrow 3Fe(s) + 2Cr^{3+}(aq)$$

19.4.5. Determine the standard potential (V) for the cell reaction.

$$3I_2(s) + 2Cr(s) \rightarrow 2Cr^{3+}(aq) + 6I^{-}(aq)$$

19.5: Standard Electrochemical Potentials

19.5.1. What is the $E°_{cell}$?

$$Cu(s) + Cd^{2+}(aq) \rightarrow Cu^{2+}(aq) + Cd(s)$$

19.5.2. What is the expression for Q, in the equation:

$$3Zn(s) + 2Fe^{3+}(aq) \rightarrow 3Zn^{2+}(aq) + 2Fe(s)$$

19.5.3. What is the E_{cell}?

$$3Zn(s) + 2Au^{3+}(0.004M) \rightarrow 3Zn^{2+}(0.0051M) + 2Au(s)$$

19.5.4. $E°_{cell}$ is +2.28V, what is ΔG?

$$3Zn(s) + 2Au^{3+}(aq) \rightarrow 3Zn^{2+}(aq) + 2Au(s)$$

19.5.5. $E°_{cell}$ is -0.763, what is the ΔG?

$$2H^{+}(aq) + Zn(s) \rightarrow H_2(g) + Zn^{2+}(aq)$$

19.6: Electrochemistry and Thermodynamics

Figure 19.2: Use the following table to answer questions 19.6.1-19.6.5

Half-reaction	$\varepsilon_{red}°$
$I_2(s) + 2e^- \rightarrow 2I^-(aq)$	0.54 V
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	-0.44 V
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	0.77 V
$Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$	-0.74 V

19.6.1. Using the given information, determine the ΔG^0 in J for the following cell reaction. F=96500J/V mol

$$2I^-(aq) + 2Fe^{3+}(aq) \rightarrow 2Fe^{2+}(aq) + I_2(s)$$

19.6.2. Using the given information, determine the ΔG^0 in J for the following cell reaction. F=96500J/V mol

$$Cr(s) + 3Fe^{3+}(aq) \rightarrow 3Fe^{2+}(aq) + Cr^{3+}(aq)$$

19.6.3. Using the given information, determine the ΔG^0 in J for the following cell reaction. F=96500J/V mol

$$Fe(s) + 2Fe^{3+}(aq) \rightarrow 3Fe^{2+}(aq)$$

19.6.4. Using the given information, determine the ΔG^0 in J for the following cell reaction. F=96500J/V mol

$$2Cr(s) + 3Fe^{2+}(aq) \rightarrow 3Fe(s) + 2Cr^{3+}(aq)$$

19.6.5. Using the given information, determine the ΔG^0 in J for the following cell reaction. F=96500J/V mol

$$3I_2(s) + 2Cr(s) \rightarrow 2Cr^{3+}(aq) + 6I^-(aq)$$

19.7: Electrochemical Cells under Nonstandard Conditions

The Nernst Equation

19.7.1. Determine the cell voltage E at 25°C, when $[Fe^{2+}]=[I^-]=0.01M$, $[Fe^{3+}]=0.02M$.

$$2I^-(aq) + 2Fe^{3+}(aq) \rightarrow 2Fe^{2+}(aq) + I_2(s), \quad E^\circ = 0.23v$$

19.7.2. Determine the cell voltage E at 25°C, when $[Fe^{2+}]=0.01M$, $[Fe^{3+}]=0.02M$

$$Fe(s) + 2Fe^{3+}(aq) \rightarrow 3Fe^{2+}(aq), \quad E^\circ = 1.21v$$

19.7.3. Determine the cell voltage E at 25°C, when $[Fe^{2+}]=0.01M$, $[Cr^{3+}]=0.005M$

$$2Cr(s) + 3Fe^{2+}(aq) \rightarrow 3Fe(s) + 2Cr^{3+}, \quad E^\circ = 0.30v$$

19.7.4. Calculate the equilibrium constant for the reaction at 25°C. R=8.314J/Kmol, F=96500 J/Vmol

$$2I^-(aq) + 2Fe^{3+}(aq) \rightarrow 2Fe^{2+}(aq) + I_2(s)$$

19.7.5. For the reaction, if the E_{cell} is 1.50v and $[Fe^{3+}]=0.02M$, determine the concentration of Fe^{2+}.

$$Fe(s) + 2Fe^{3+}(aq) \rightarrow 3Fe^{2+}(aq)$$

Galvanic Cell Potentials

Figure 19.3: Use the following reactions to answer questions 19.7.6-19.7.11.

Cell 1:

$$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s) \quad -0.44volts$$

$$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s) \quad -2.37volts$$

Cell 2:

$$Ga^{3+}(aq) + 3e^- \rightarrow Ga(s) \quad -0.53volts$$

$$Mn^{2+}(aq) + 2e^- \rightarrow Mn(s) \quad -1.18volts$$

Cell 3:

$$Au^{3+}(aq) + 3e^- \rightarrow Au(s) \quad 1.50volts$$

$$Sr^{2+}(aq) + 2e^- \rightarrow Sr(s) \quad -2.89volts$$

19.7.6. Find the following values for cell 1.

a. What is the $E°_{cell}$ for cell 1?

b. What is the $\Delta G°_{rxn}$ for cell 1?

19.7.7. What is the E_{cell} for cell 1(0.4M Mg^{2+} and 1.4M Fe^{2+})?

19.7.8. Find the following values for cell 2.

a. What is the $E°_{cell}$ for cell 2?

b. What is the $\Delta G°_{rxn}$ for cell 2?

19.7.9. What is the E_{cell} for cell 2(0.5M Mn^{2+} and 1.5M Ga^{3+})?

19.7.10. Find the following values for cell 3.

a. What is the $E°_{cell}$ for cell 3?

b. What is the $\Delta G°_{rxn}$ for cell 3?

19.7.11. What is the E_{cell} for cell 3(1.2M Sr^{2+} and 0.6M Au^{3+})?

19.9: Electrolysis

19.9.1. How many minutes will it take to plate out 2.50g of chromium metal from Cr^{3+} solution using a current of 32.0 amps?

19.9.2. What current (in A) is needed to plated out 1.50g of chromium metal from Cr^{3+} solution in 30sec?

19.9.3. How many grams of copper can be obtained if a current of 10amps passes through a solution of copper (II) sulfate for 20min?

19.9.4. In an electrolytic cell, 0.05g of copper was produced from the copper (II) sulfate solution. How many grams of potassium would be plated out if the same current was applied through molten KCl?

19.9.5. Calculate the number of kilowatt-hrs of electricity required to produce 1.00kg of Al by electrolysis of Al^{3+} if 5.00V of emf is applied.

General Questions

19.1. In the voltaic cell that is represented as

$$Cd \mid Cd^{2+} \mid\mid (Pt)\ Fe^{3+} \mid Fe^{2+}$$

the electron flow will be from

a. Pt to Cd^{2+}
b. Pt to Cd
c. Fe^{2+} to Cd^{2+}
d. Cd^{2+} to Fe^{2+}
e. Cd to Fe^{3+}

19: Electron Transfer Reactions

19.2. In the voltaic cell that is represented as

$$Zn(s) \mid Zn^{2+}(1.0\ M) \mid\mid Cu^{2+}(1.0\ M) \mid Cu(s)$$

Which of the following statements is <u>false</u>?

a. The mass of the zinc electrode decreases during discharge.
b. The copper electrode is the anode.
c. Electrons flow through the external circuit from the zinc electrode to the copper electrode.
d. Reduction occurs at the copper electrode during discharge.
e. The concentration of Cu^{2+} decreases during discharge.

19.3. For a galvanic cell using $Fe|Fe^{2+}(1.0\ M)$ and $Pb|Pb^{2+}(1.0\ M)$ half-cells, which of the following statements is correct?

$$Fe^{2+} + 2e^- \rightarrow Fe \quad -0.44\ V$$
$$Pb^{2+} + 2e^- \rightarrow Pb \quad -0.13\ V$$

a. The mass of the iron electrode decreases during discharge.
b. Electrons leave the lead electrode to pass through the external circuit during discharge.
c. The concentration of Pb^{2+} increases during discharge.
d. The iron electrode is the cathode.
e. When the cell has completely discharged (to zero voltage), the concentration of Pb^{2+} is zero.

19.4. What is the cell reaction of the voltaic cell $Cr(s)|Cr^{3+}(aq)||Cl^-(aq)|Cl_2(g)|Pt$?

19.5. When Au is obtained by electrolysis from $NaAuCl_4$, what is the minimum number of coulombs required to produce 1.00 mol of gold?

19.6. How many faradays are required to convert a mole of $Cr_2O_7^{2-}$ to Cr^{3+}?

19.7. Which of the following cell reactions would require the use of an inert electrode?

1. $Zn(s) + 2MnO_2(s) + 2NH_4{}^+(aq) \rightarrow Zn^{2+}(aq) + Mn_2O_3(s) + 2NH_3(aq) + H_2O(l)$
2. $Zn(s) + 2Ag^+(aq) \rightarrow Zn^{2+}(aq) + 2Ag(s)$
3. $3Cu(s) + 2Au^{3+}(aq) \rightarrow 3Cu^{2+}(aq) + 2Au(s)$
4. $Cl_2(g) + 2I^-(aq) \rightarrow 2Cl^-(aq) + I_2(s)$

a. 1 only
b. 1 and 3 only
c. 2 and 3 only
d. 1 and 4 only
e. 3 and 4 only

19.8. How many moles of electrons are produced form a current of 15.0 A in 1.00 hr?

19.9. The following has a potential of 0.92 V:

$$2Hg^{2+}(aq) + H_2(g) \rightarrow 2H^+(aq) + Hg_2{}^{2+}(aq)$$

If the concentration of the ions were 1.0 molar and the pressure of H_2 were 1.0 atmosphere, then what would be the E° for the half-reaction?

$$2Hg^{2+}(aq) + 2e^- \rightarrow Hg_2{}^{2+}$$

19.10. A cell with the potential of 0.74 V has the cell reaction

$$2Cr + 6H^+ \rightarrow 2Cr^{3+} + 3H_2$$

If the concentrations of the ions were 1.0 molar and the pressure of H_2 were 1.0 atmosphere, then what would be the E° of the half-reaction?

$$Cr^{3+} + 3e^- \rightarrow Cr$$

19.11. A standard cell that consisted of a strip of zinc dipped into 1.0 M zinc ion and a strip of copper dipped into 1.0 M copper ion and which was connected by a salt bridge had a potential of 1.10 V

$$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$$

If a potential of 0.60 V were assigned to the half-reaction

$$Cu^{2+} + 2e^- \rightarrow Cu$$

instead of 0.34 V, which is the potential given in a standard reduction potential table, the potential for the reaction would be

$$Zn^{2+} + 2e^- \rightarrow Zn$$

19.12. Consider the following electrode potentials:

$$Mg^{2+} + 2e^- \rightarrow Mg \quad E^0 = -2.37V$$

$$V^{2+} + 2e^- \rightarrow V \quad E^0 = -1.18V$$

$$Cu^{2+} + e^- \rightarrow Cu^+ \quad E^0 = 0.15V$$

Which one of the reactions below will proceed spontaneously from left to right?

a. $Mg^{2+} + V \rightarrow V^{2+} + Mg$
b. $Mg^{2+} + 2Cu^+ \rightarrow 2Cu^{2+} + Mg$
c. $V^{2+} + 2Cu^+ \rightarrow V + Cu^{2+}$
d. $V + 2Cu^{2+} \rightarrow V^{2+} + 2Cu^+$
e. none of these

19.13. Consider the following standard reduction potentials:

$$2H^+(aq) + 2e^- \rightarrow H_2(g) \quad E^0 = 0.00\ V$$

$$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s) \quad E^0 = -0.15\ V$$

$$Cd^{2+}(aq) + 2e^- \rightarrow Cd(s) \quad E^0 = -0.40\ V$$

which pair of substances react spontaneously

a. Sn^{2+} with Cd^{2+}
b. Sn with Cd^{2+}
c. Sn^{2+} with H^+
d. Cd with Sn
e. Cd with Sn^{2+}

19.14. Calculate the maximum electrical work obtained when 7.10 grams of Cl_2 gas are consumed in the reaction $Cd(s) + Cl_2(g) \rightleftharpoons Cd^{2+}(aq) + 2\ Cl^-(aq)$. ($E_{cell}$=1.76V)

19.15. Calculate E° for the cell reaction $2Cr + 3Sn^{4+} \rightarrow 3Sn^{2+} + 2Cr^{3+}$.

$$Cr^{3+} + 3e^- \rightarrow Cr \quad E^0 = -0.74\ V$$
$$Sn^{4+} + 2e^- \rightarrow Sn^{2+} \quad E^0 = 0.15\ V$$

19.16. At 25°C, calculate the voltage of the cell

$$2Ag^+(aq)(0.16\ M)\ +\ Cu(s) \rightarrow Cu^{2+}(aq)(0.015\ M) + 2Ag(s)$$

if E°_{cell} = 0.460 V.

Figure 19.4: Use the following information for Questions 19.17-19.18

$$Cr^{3+} + 3e^- \rightarrow Cr \quad -0.74\,V$$

$$Pb^{2+} + 2e^- \rightarrow Pb \quad -0.13\,V$$

19.17. What is the standard cell potential for the reaction?

$$2Cr + 3Pb^{2+} \rightarrow 3Pb + 2Cr^{3+}$$

19.18. Calculate the Gibbs free energy change for the reaction above the initial concentration of Cr^{3+} and Pb^{2+} are 1.00M.

19.19. What is the value of the reaction quotient, Q, for the cell that is constructed form the two half-reactions?

$$Zn^{2+} + 2e^- \rightarrow Zn \quad -0.76\,V$$

$$Ag^+ + e^- \rightarrow Ag \quad 0.80\,V$$

when the Zn^{2+} concentration is 0.0100 M and the Ag^+ concentration is 1.25M?

19.20. Calculate ΔG° (in joules) for the reaction $2AlI_3(aq) \rightleftharpoons 2Al(s) + 3I_2(s)$.

$$Al^{3+} + 3e^- \rightleftharpoons Al \quad E^0 = -1.66\,V$$
$$I_2(s) + 2e^- \rightleftharpoons 2I^1 \quad E^0 = 0.54\,V$$

19.21. What is the reduction potential for the half-reaction $Al^{3+}(aq) + 3e^- \rightarrow Al(s)$ + at 25°C is $[Al^+]$ = 0.10 M and E° = -1.66 V?

19.22. What is the emf at 25°C for the following cell?

$$Cr \mid Cr^{3+}(0.010\,M) \mid\mid Ag^+\,(0.00010\,M) \mid Ag$$

$$Cr^{3+} + 3e^- \rightleftharpoons Cr \quad E^0 = -0.74\,V$$
$$Ag^+ + e^- \rightleftharpoons Ag \quad E^0 = 0.80\,V$$

19.23. What is the Cu^{2+} concentration at 25°C in the cell Zn(s) | Zn^{2+} (1.0 M) || Cu^{2+}(aq) | Cu(s)? The cell emf is 1.03 V. The standard cell emf is 1.10 V.

19.24. Molten magnesium chloride is electrolyzed using insert electrodes and reactions represented by the following equations

$$2Cl^{-} \rightarrow Cl_2 + 2e^{-}$$

$$Mg^{2+} + 2e^{-} \rightarrow Mg$$

concerning this electrolysis which of the following statements is true

a. oxidation occurs at the cathode
b. Mg^{2+} ions are reduced at the anode
c. electrons pass through the metallic part of the circuit from Mg^{2+} ions to the Cl^{-} ion
d. Cl^{-} ions are oxidizing agents
e. the cations and the electrolyte undergo reduction

19.25. A piece of iron half immerse in a sodium chloride solution will corrode more rapidly than a piece of iron half immersed in pure water because

a. the sodium iron oxidized the iron atoms
b. the chloride ions oxidized the iron atoms
c. the chloride ions form a precipitate with iron
d. the chloride ions increase the pH of the solution
e. the sodium ions and chloride ions carry a current through the solution

19.26. A reaction is spontaneous win

a. ΔG° is negative or E° is positive
b. ΔG° is negative or E° is negative
c. ΔG° is positive or E° is negative
d. ΔG° is positive or E° is positive
e. ΔG° is negative, ΔH° is negative, and E° is negative

19.27. What reaction occurs at the cathode during electrolysis of aqueous $CuSO_4$?

a. $2H_2O + 2e^{-} \rightarrow H_2 + 2OH^{-}$
b. $Cu \rightarrow Cu^{2+} + 2e^{-}$
c. $2H_2O \rightarrow O_2 + 4H^{+} + 4e^{-}$
d. $2H^{+} + 2e^{-} \rightarrow H_2$
e. $Cu^{2+} + 2e^{-} \rightarrow Cu$

19.28. For a certain oxidation-reduction reaction, he is positive. this means that

a. $\Delta G°$ is negative and K is less than 1
b. $\Delta G°$ is negative and K is greater than 1
c. $\Delta G°$ is zero and K is greater than 1
d. $\Delta G°$ is positive and K is greater than 1
e. $\Delta G°$ is positive and K is less than 1

19.29. Cathodic protection results when

a. iron is attached to a more active metal
b. iron is amalgamated with Mercury
c. iron is tin plated for use as a tin can
d. iron is painted to protect it from corrosion
e. iron is made amphoteric

19.30. What mass of chromium could be deposited by electrolysis of an aqueous solution fo $Cr_2(SO_4)_2$ for 60.0 minutes using constant current of 10.0 amperes? (One faraday = 96,500 coulombs.)

19.31. In a galvanic cell porn electrolysis cell, the cathode is always

a. the positive electrode
b. the negative electrode
c. the positive electrode and the negative electrode, respectively
d. the electrode at which some species gain electrons
e. the electrode at which some species lose electrons

19.32. The voltage of the cell at 25°C would be

$$Zn^{2+} + 2e^- \rightarrow Zn \quad E^0 = -0.76\ V$$

$$Cu^{2+} + 2e^- \rightarrow Cu \quad E^0 = 0.34\ V$$

a. between 0.76 and 1.10V
b. between 0.34 and 0.76 V
c. between 0.00 and 0.76 speak
d. less than 0.42 V
e. greater than 1.10 V

19.33. On the basis afford going standard electrode potentials, determine which of the following is the strongest oxidizing agent.

$$Zn^{2+} + 2e^- \rightarrow Zn \quad E^0 = -0.76\,V$$

$$Cu^{2+} + 2e^- \rightarrow Cu \quad E^0 = +0.34\,V$$

$$Cr_2O_7{}^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O \quad E^0 = +1.33\,V$$

a. Zn^{2+}
b. Zn
c. Cu
d. $Cr_2O_7{}^{2-}$
e. Cr^{3+}

19.34. Which of the following species is the best reducing agent?

a. Cd
b. Mg^{2+}
c. I^-
d. Sn
e. F^-