Balancing Reaction Equations
Oxidation State
Reduction-oxidation Reactions

OCN 623 – Chemical Oceanography

Balanced chemical reactions are the math of chemistry

They show the relationship between the reactants and the products

We will use thermodynamics later on to calculate the feasibility of reactions and to understand how equilibrium is established

The concept of equilibrium allows us to understand chemical processes such as ionic speciation, oxidation state distributions, gas solubility, the carbonate system ……
Outline

- Types of reactions and equations
- Net ionic equations
- Electron-transfer reactions
- Common oxidation states of elements
- Determining oxidation number of elements & compounds
- Reduction-oxidation reactions

Summary of Types of Reactions and Equations

<table>
<thead>
<tr>
<th>Reactants</th>
<th>Reaction Type</th>
<th>Products</th>
<th>Reference</th>
</tr>
</thead>
</table>
| Element + element
Element + compound
Compound + compound | Combination | One compound | Equation 8.8 |
| One compound | Decomposition | Element + element
Element + compound
Compound + compound | Equation 8.9 |
| O₂ + compound of C, H, and O | Complete oxidation or burning | CO₂ + H₂O* | Equation 8.10 |
| Element + ionic compound or acid *** | Oxidation–Reduction† | Element + ionic compound | Equation 8.11 |
| Two ionic compounds | Precipitation‡ | Two ionic compounds | Equation 8.12 |
| Acid + base | Neutralization§ | Ionic compound (salt) + H₂O | Equation 8.13 |

*The reactant oxygen and the products carbon dioxide and water are usually not mentioned in the description of a reaction of this kind.  
†There are several kinds of oxidation-reduction reactions. The one described in this chapter occurs in water solution. Its equation is called a single replacement equation.  
‡Precipitation and neutralization reactions are usually described by a double replacement equation.
Net Ionic Equations

An example:

If a solution of lead nitrate is added to a solution of sodium chloride, lead chloride precipitates:

\[
Pb(NO_3)_2(aq) + 2 NaCl(aq) \rightarrow PbCl_2(s) + 2 NaNO_3(aq)
\]
(This is a conventional equation)

To better describe the reaction, the formulas of the dissolved substances are replaced with the actual species in solution:

\[
Pb^{2+}(aq) + 2 NO_3^-(aq) + 2 Na^+(aq) + 2 Cl^-(aq) \rightarrow
\]
\[
PbCl_2(s) + 2 Na^+(aq) + 2 NO_3^-(aq)
\]
(This is an ionic equation)

We can then eliminate the “spectators”.

The result is a net ionic equation, which tells exactly what chemical change took place, and nothing else:

\[
Pb^{2+}(aq) + 2 Cl^-(aq) \rightarrow PbCl_2(s)
\]

Steps in writing a net ionic equation:

- Write the conventional equation, including designations of state [(g), (l), (s), (aq)]. Balance the equation.

- Write the ionic equation by replacing each dissolved substance (aq) with the species in solution. Never change states in this step. Be sure the equation is balanced for both atoms and charge.

- Write the net ionic equation by removing the spectators. Reduce coefficients to lowest terms. Be sure the equation is balanced for both atoms and charge.
Electron-transfer Reactions

*Example:* H₂ combining with O₂ to form water:

\[ 2 \text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} \]

An electron is transferred from H to O:
the H₂ is oxidized and the O₂ is reduced

We use the oxidation number (oxidation state) to keep track of electron shifts in chemical reactions. It is defined as “the charge which an atom appears to have when the net electric charge on a chemical species is apportioned according to certain rules”.

Important because: the binding of atoms can result from the transfer or sharing of electrons.

Oxidation state or number

Oxidation: Loss of electrons from an element.
Oxidation number *increases*

Reduction: Gain of electrons by an element.
Oxidation number *decreases*

If we want to determine whether reaction is oxidation or reduction

Need to know oxidation number of the element and how it changes
s-block

d-block

f-block

p-block

Lanthanides

Actinides

He

Ce

Th
**Orbitals**

<table>
<thead>
<tr>
<th>Principal Quantum Number</th>
<th>s</th>
<th>p</th>
<th>d</th>
<th>f</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1s</td>
<td>2s</td>
<td>2p</td>
<td>3s</td>
</tr>
<tr>
<td>2</td>
<td>3s</td>
<td>3p</td>
<td>4s</td>
<td>3d</td>
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<td>4p</td>
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<tr>
<td>4</td>
<td>5s</td>
<td>5p</td>
<td>6s</td>
<td>5d</td>
</tr>
<tr>
<td>5</td>
<td>6s</td>
<td>6p</td>
<td>7s</td>
<td>6d</td>
</tr>
<tr>
<td>6</td>
<td>7s</td>
<td>7p</td>
<td>7d</td>
<td>7f</td>
</tr>
</tbody>
</table>

**Element**

<table>
<thead>
<tr>
<th>Hydrogen</th>
<th>1s^1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium</td>
<td>1s^2</td>
</tr>
<tr>
<td>Lithium</td>
<td>1s^2 2s^1</td>
</tr>
<tr>
<td>Beryllium</td>
<td>1s^2 2s^2</td>
</tr>
<tr>
<td>Boron</td>
<td>1s^2 2s^2 2p^6 3s^1</td>
</tr>
<tr>
<td>Carbon</td>
<td>1s^2 2s^2 2p^6 3s^2 3p^2</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>1s^2 2s^2 2p^6 3s^2 3p^3</td>
</tr>
<tr>
<td>Oxygen</td>
<td>1s^2 2s^2 2p^6 3s^2 3p^4</td>
</tr>
<tr>
<td>Fluorine</td>
<td>1s^2 2s^2 2p^6 3s^2 3p^5</td>
</tr>
<tr>
<td>Neon</td>
<td>1s^2 2s^2 2p^6 3s^2 3p^6</td>
</tr>
<tr>
<td>Sodium</td>
<td>1s^2 2s^2 2p^6 3s^2 3p^6 4s^1</td>
</tr>
<tr>
<td>Magnesium</td>
<td>1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1</td>
</tr>
<tr>
<td>Aluminium</td>
<td>1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3p^3</td>
</tr>
<tr>
<td>Silicon</td>
<td>1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3p^4</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3p^3 3d^1</td>
</tr>
<tr>
<td>Sulfur</td>
<td>1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3p^3 3d^2 4p^1</td>
</tr>
<tr>
<td>Chlorine</td>
<td>1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3p^3 3d^2 4p^2</td>
</tr>
<tr>
<td>Argon</td>
<td>1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3p^6 4d^10</td>
</tr>
</tbody>
</table>

**Electronic Configuration Table**

d block have energy level "n-1", therefore while the s block have n = 4, the d block will have n = 3 as shown on the periodic table.
Determining Oxidation Number of Elements & Compounds

1. In uncombined or free elements (not ionized), each atom has an oxidation number of 0. E.g., all of the atoms in these molecules: H$_2$, Na, S$_8$, O$_2$, P$_4$.

2. In simple ions (i.e., charged species which contain only one atom), the oxidation number is equal to the charge on the ion. E.g., Na and K only form +1 ions; thus, their oxidation numbers are +1 in all compounds (see Fig. 20.1).

Determining Oxidation Number of Elements & Compounds

3. Oxidation state of certain elements is the same in all, or almost all of their compounds

e.g.,
Group 1A elements: Li, Na, K, Rb, Cs = +1
Group 2A elements: Be, Mg, Ca, Sr, Ba, Ra = +2
Group VIIb elements: F, Cl, Br, I, At = -1 in binary compounds
Oxygen is almost always -2 (except when bonded to O or F)
H is almost always +1 (except with a metal; NaH, CaH$_2$ is -1)
4. Oxidation numbers must be consistent with conservation of charge. *E.g.,* The sum of charge must be 0 for neutral molecules.

For H₂O:
- H: oxid number is +1
- O: oxid number is –2

Net charge = 2(+1) + 1(-2) = 0

For MnO₄⁻: O= -2x4= -8, thus Mn= 8-1= 7

5. Fractional oxidation numbers are possible. *E.g.,* in Na₂S₄O₆ (sodium tetrathionate), S has an oxidation number of +10/4:

- O: 6(-2) = -12
- Na: 2(+1) = 2

Residual = -10, which must be balance by S:

- S: 4(+10/4) = +10

6. The oxidation number is designated by:
   - Arabic number below the atom, or
   - Roman numberal or arabic number after the atom (in parentheses)
Common Oxidation States of Elements

Oxidation states for important N, S and C compounds:

<table>
<thead>
<tr>
<th>Nitrogen Compounds</th>
<th>Sulfur Compounds</th>
<th>Carbon Compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substance Oxidation States</td>
<td>Substance Oxidation States</td>
<td>Substance Oxidation States</td>
</tr>
<tr>
<td>NH₄⁺ N = −III, H = +I</td>
<td>H₂S S = −II, H = +I</td>
<td>HCO₃⁻ C = −I</td>
</tr>
<tr>
<td>N₂ N = 0</td>
<td>S₂(6) S = 0</td>
<td>HCOOH C = +II</td>
</tr>
<tr>
<td>NO₂⁻ N = +III, O = −II</td>
<td>SO₄²⁻ S = +IV, O = −II</td>
<td>C₂H₅OH C = 0</td>
</tr>
<tr>
<td>NO₃⁻ N = +V, O = −II</td>
<td>SO₂⁻ S = +VI, O = −II</td>
<td>CH₄ C = −IV</td>
</tr>
<tr>
<td>HCN N = −III, C = +II, H = +I</td>
<td>S₂O₃²⁻ S = +II, O = −II</td>
<td>C₂H₅COOH C = −2/7</td>
</tr>
<tr>
<td>SCN⁻ S = −I, C = +III, N = −III</td>
<td>S₂O₄²⁻ S = +2.5, O = −II</td>
<td></td>
</tr>
</tbody>
</table>
Reduction-Oxidation Reactions

Oxidation is a chemical process in which an atom shows an increase in oxidation number.

Reduction is a chemical process in which an atom shows a decrease in oxidation number.

Example: \[ 2 \text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} \]

- The hydrogen changes oxidation number from 0 to +1 (is oxidized).
- The oxygen changes oxidation number from 0 to −2 (is reduced).
In general

Oxidant (Oxidizing agent)  \[ \rightarrow \]  Reduced product  
Reduction (gain of \( e^- \))  

Reductant (Reducing agent)  \[ \rightarrow \]  Oxidized product  
Oxidation (loss of \( e^- \))

Because there are no free electrons in nature, every oxidation is accompanied by a reduction, and vice versa.

---

**Oxidation of zinc:**  \[ \text{Zn (s)} + 2 \text{H}^+ \rightarrow \text{Zn}^{2+} + \text{H}_2 (g) \]

\[ 2 \text{H}^+ \quad \text{Zn (s)} \quad \text{Zn}^{2+} \]

\[ +1 \quad \rightarrow \quad 0 \quad +2 \]

\[ \text{H}_2 (g) \]

\[ 0 \]
FIG. 2.3 Terms Used in Describing Oxidation-Reduction

<table>
<thead>
<tr>
<th>Term</th>
<th>Change in oxidation number</th>
<th>Change in electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxidation</td>
<td>Increase</td>
<td>Loss of electrons</td>
</tr>
<tr>
<td>Reduction</td>
<td>Decrease</td>
<td>Gain of electrons</td>
</tr>
<tr>
<td>Oxidizing agent</td>
<td>Decrease</td>
<td>Accepts electrons</td>
</tr>
<tr>
<td>Reducing agent</td>
<td>Increase</td>
<td>Donates electrons</td>
</tr>
<tr>
<td>Substance oxidized</td>
<td>Increase</td>
<td>Loses electrons</td>
</tr>
<tr>
<td>Substance reduced</td>
<td>Decrease</td>
<td>Gains electrons</td>
</tr>
</tbody>
</table>

Note: Strengths not necessarily related to # of electrons transferred

Table 18.1 Relative Strengths of Oxidizing and Reducing Agents

<table>
<thead>
<tr>
<th>Oxidizing Agent</th>
<th>Reducing Agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>F₂(g) + 2e⁻</td>
<td>2 F⁻</td>
</tr>
<tr>
<td>Cl₂(g) + 2e⁻</td>
<td>2 Cl⁻</td>
</tr>
<tr>
<td>( \frac{1}{2} ) O₂(g) + 2 H⁺ + 2e⁻</td>
<td>H₂O</td>
</tr>
<tr>
<td>Br₂(f) + 2e⁻</td>
<td>2 Br⁻</td>
</tr>
<tr>
<td>NO₃⁻ + 4 H⁺ + 3e⁻</td>
<td>NO(g) + 2 H₂O</td>
</tr>
<tr>
<td>Ag⁺ + e⁻</td>
<td>Ag(s)</td>
</tr>
<tr>
<td>Fe³⁺ + e⁻</td>
<td>Fe²⁺</td>
</tr>
<tr>
<td>I₂(s) + 2e⁻</td>
<td>2 I⁻</td>
</tr>
<tr>
<td>Cu²⁺ + 2e⁻</td>
<td>Cu(s)</td>
</tr>
<tr>
<td>2 H⁺ + 2e⁻</td>
<td>H₂(g)</td>
</tr>
<tr>
<td>Ni²⁺ + 2e⁻</td>
<td>Ni(s)</td>
</tr>
<tr>
<td>Co²⁺ + 2e⁻</td>
<td>Co(s)</td>
</tr>
<tr>
<td>Cd²⁺ + 2e⁻</td>
<td>Cd(s)</td>
</tr>
<tr>
<td>Fe²⁺ + 2e⁻</td>
<td>Fe(s)</td>
</tr>
<tr>
<td>Zn²⁺ + 2e⁻</td>
<td>Zn(s)</td>
</tr>
<tr>
<td>Al³⁺ + 3e⁻</td>
<td>Al(s)</td>
</tr>
<tr>
<td>Na⁺ + e⁻</td>
<td>Na(s)</td>
</tr>
<tr>
<td>Cu²⁺ + 2e⁻</td>
<td>Cu(s)</td>
</tr>
<tr>
<td>Li⁺ + e⁻</td>
<td>Li(s)</td>
</tr>
</tbody>
</table>

Note: Strengths not necessarily related to # of electrons transferred
Procedure for balancing redox reactions in aqueous solutions:

1. Identify the principal reactants and products, that is, species other than \( H^+ \), \( OH^- \), and \( H_2O \), in the oxidation half-reaction and the reduction half-reaction and write each half-reaction in crude form.

2. Then to obtain balanced half-reactions, balance the atoms other than hydrogen and oxygen by multiplying the reactants or products by appropriate integers.

3. Balance the oxygen using \( H_2O \).

4. Balance the hydrogen with \( H^+ \).

5. Balance the charge with electrons.

6. Multiply each half-reaction by an appropriate integer so that both contain the same number of electrons.

7. Add the two balanced half-reactions.

8. Steps 1 to 7 will sometimes produce an equation that has \( H^+ \) as a reactant or a product. If it is known that the reaction takes place in alkaline solution, add the reaction for dissociation of water to the balanced equation to eliminate \( H^+ \) and form \( H_2O \).

Example 7-1

Balance the reaction in which ferrous iron (\( Fe^{2+} \)) is oxidized to ferric iron (\( Fe^{3+} \)) by permanganate (\( MnO_4^- \)), which itself is reduced to manganese dioxide (\( MnO_2 \)). The reaction takes place in alkaline solution.

Solution

1. The reactants and products are
   \[
   Fe^{2+} \rightleftharpoons Fe^{3+} \quad \text{(oxidation)} \\
   MnO_4^- \rightleftharpoons MnO_2 + 2H_2O \quad \text{(reduction)}
   \]

2. The atoms other than H and O are already balanced.

3. Balance the oxygen with water:
   \[
   Fe^{2+} \rightleftharpoons Fe^{3+} \\
   MnO_4^- \rightleftharpoons MnO_2 + 2H_2O
   \]

4. Balance the hydrogen with \( H^+ \):
   \[
   4H^+ + MnO_4^- \rightleftharpoons MnO_2 + 2H_2O
   \]

5. Balance the charge with electrons, \( e^- \):
   \[
   Fe^{2+} \rightleftharpoons Fe^{3+} + e^- \\
   3e^- + 4H^+ + MnO_4^- \rightleftharpoons MnO_2 + 2H_2O
   \]
Q: How do we know that this happens?

Oxidation of organic matter

\[ \text{CH}_2\text{O} + \text{SO}_4^{2-} + \text{H}_2\text{O} = \text{CO}_2 + \text{H}_2\text{S} \]

0 \quad \text{IV} \quad \text{ox state of C}

(How did we get the oxidation state of the C in CH\(_2\)O?)

Separate into oxidation and reduction half reactions

\[ \text{SO}_4^{2-} + 8\text{e}^- + 10 \text{H}^+ = \text{H}_2\text{S} + 4\text{H}_2\text{O} \quad \text{A} \]

\[ \text{CH}_2\text{O} + \text{H}_2\text{O} = \text{CO}_2 + 4\text{H}^+ + 4 \text{e}^- \quad \text{B} \]
Combine so electrons balance:
A + B*2

2 CH₂O + SO₄²⁻ +2 H₂O + 10H⁺ = H₂S + 4 H₂O + 2 CO₂ + 8 H⁺

Simplify by subtracting 8 H⁺ and 2 H₂O from each side.

2 CH₂O + SO₄²⁻ +2H⁺ = H₂S + 2 H₂O + 2 CO₂

This reaction is the oxidation of organic matter through the reduction of sulphate, you will see this reaction later in reducing sediments.

**D. An example in basic solution:**

I⁻ + MnO₄⁻ = I₂ + MnO₂

Oxidation: 2I⁻ = I₂ + 2e⁻  **A**
Reduction: MnO₄⁻ + 4H⁺ +3e⁻ = MnO₂ + 2H₂O

remove H⁺ by adding OH⁻ to each side * 4 (4H⁺ + 4OH⁻ = 4 H₂O)

MnO₄⁻ + 4 H₂O⁺ +3e⁻ = MnO₂ + 2H₂O + 4OH⁻
simplify: MnO₄⁻ + 2 H₂O +3e⁻ = MnO₂ + 4OH⁻  **B**

combine so electrons balance: A * 3 + B * 2

6I⁻ + 2MnO₄⁻ + 4H₂O = 3I₂ + 2MnO₂ + 8OH⁻
E. A weathering reaction.

Fe$_2$SiO$_4$ + O$_2$ = Fe$_2$O$_3$ + FeSiO$_3$

II  III  II ox state of Fe i.e. Fe is oxidised

Iron Olivine = Haematite + Ferrosilite (Fe pyroxene)

Separate and balance for mass and charge

O$_2$ + 4 e$^-$ = 2O$^{2-}$  \text{reduction A}

2Fe$_2$SiO$_4$ + H$_2$O = Fe$_2$O$_3$ + 2e$^-$ + 2FeSiO$_3$ + 2H$^+$  \text{oxidation B}

Note have added H$_2$O on LH side

Combine eqns balancing e$^-$. A+ 2*B

4Fe$_2$SiO$_4$ + 2H$_2$O + O$_2$ + 4 e$^-$ = 2Fe$_2$O$_3$ + 4 e$^-$ + 4FeSiO$_3$ + 4H$^+$ + 2O$^{2-}$

cancel 4e$^-$ on each side then cancel as 2H$_2$O = 4H$^+$ + 2O$^{2-}$

4Fe$_2$SiO$_4$ + O$_2$ = 2Fe$_2$O$_3$ + 4FeSiO$_3$

Removal of oxygen by oxidation of reduced iron compounds

Example where the same compound is being oxidised and reduced:

Cl$_2$ + H$_2$O = HOCI + H$^+$ + Cl$^-$

Cl$_2$ + 2e$^-$ = 2Cl$^-$ (reduction of Cl)

Cl$_2$ + 2H$_2$O = 2 HOCI + 2H$^+$ + 2e$^-$ (oxidation of Cl)

2Cl$_2$ + 2H$_2$O = 2 HOCI + 2H$^+$ + 2 Cl$^-$

This may have been what happened to Cl$_2$ released from the degassing of the early Earth.
More Info On Term Paper Preproposal Assignment

The Deep Carbon Observatory (DCO) is a global community of multi-disciplinary scientists unlocking the inner secrets of Earth through investigations into life, energy, and the fundamentally unique chemistry of carbon.

Example of a Foundation Call for Proposals

Pre-Proposals Invited for Oceanographic Research on R/V Falkor in 2016

Schmidt Ocean Institute invites Expressions of Interest in collaborative research cruises on R/V Falkor in 2016. The 2016 research cruise planning process is in progress, and we anticipate that the R/V Falkor will be operating in the Western Pacific Ocean in 2016. The target region of scientific operations for 2016 will be determined based on the review of the Expressions of Interest received in response to this call.

R/V Falkor 2016 research cruise planning process will progress through the following stages:

1) Open call for 1-2 page Expressions of Interests in collaborative research on R/V Falkor will continue through December 6, 2013 (current scheduling estimate).
Guidelines for Expression of Interest

Schmidt Ocean Institute aims to support research projects that demonstrate strong alignment with the Vision and Mission of the Institute and will contribute to the creation of a long-term unique legacy in ocean research and exploration on behalf of our Founders.

These projects will typically have strong promise to advance global ocean research and exploration through effective, exemplary use of innovative technologies, will be likely to produce impact on a global scale, may be out of funding focus of various conventional funding agencies, may be higher risk than projects usually supported by other funding agencies, yet will offer even higher potential return, will substantially and uniquely benefit from a collaboration with the Schmidt Ocean Institute, and will be fully committed to openly sharing the research findings, developments, and resulting scientific data.

Expression of Interest Format:

- One cover page plus no more than 2 pages, including the body text written in single-spaced 12 point font, any figures, tables, references, and any other supplementary materials
- Electronic submissions in MS Word and PDF format will be accepted in email at proposals@schmidtsoceain.org through December 6, 2013

Vision and Mission

Schmidt Ocean Institute supports oceanographic research projects that help expand the understanding of the world’s oceans through technological advancements, intelligent observation and analysis, and open sharing of information.

Vision

The world’s oceans understood through technological advancement, intelligent observation, and open sharing of information.

Mission

We combine advanced science with state-of-the-art technology to achieve lasting results in ocean research, to catalyze sharing of the information, and to communicate this knowledge to audiences around the world. We foster a deeper understanding of our environment.

Our mission is intentionally broad, as we approach ocean research from the technological, operational, and informational perspectives. We maintain and operate RV Falkor as a technologically advanced oceanographic platform suitable for multidisciplinary research. We provide our collaborators with free access to RV Falkor with her on-board equipment and associated technical support in exchange for a commitment to openly share the resulting scientific data and communicate the research findings.

R/V Falkor underway. Image credit: Schmidt Ocean Institute

R/V Falkor during the first sea trials. “The purpose of this ship, as she travels on her various missions, is to communicate about the sciences of the oceans to people so that they can care about it. We can’t take care of something that we don’t understand and we can’t care if we don’t know.” - Wendy Schmidt, March 6, 2012. Image credit: Wendy Schmidt
Homework due Thursday January 23

Term paper topics are due 2/13...don't procrastinate on this. Start brainstorming broad topics, do literature searches to narrow, talk to profs & peers.

1
Give the oxidation states of the elements in the following compounds:

<table>
<thead>
<tr>
<th>Compound</th>
<th>Oxidation State</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH₄⁺</td>
<td>+1</td>
</tr>
<tr>
<td>N₂O</td>
<td>-1</td>
</tr>
<tr>
<td>NO₃⁻</td>
<td>-3</td>
</tr>
<tr>
<td>HNO₃</td>
<td>+5</td>
</tr>
<tr>
<td>Mn(OH)₂</td>
<td>+2</td>
</tr>
<tr>
<td>MnO₂</td>
<td>+4</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>+5</td>
</tr>
<tr>
<td>BrO₃⁻</td>
<td>+5</td>
</tr>
<tr>
<td>HSO₃⁻</td>
<td>-1</td>
</tr>
<tr>
<td>K₂Cr₂O₇</td>
<td>+7</td>
</tr>
<tr>
<td>FeSO₄</td>
<td>+2</td>
</tr>
<tr>
<td>Fe₂O₄₃</td>
<td>+3</td>
</tr>
<tr>
<td>CuMg(CO₃)₂</td>
<td>-2</td>
</tr>
<tr>
<td>Fe₂O₄</td>
<td>+3</td>
</tr>
<tr>
<td>Al₂SiO₅(OH)₄</td>
<td>0</td>
</tr>
</tbody>
</table>

2
Balance the following equations:

Mn(OH)₂ + O₂ → Mn(OH)₃
KMnO₄ + Na₂SO₃ → MnO₂ + Na₂SO₄ + K⁺
S₈ + NO₃⁻ → SO₄²⁻ + NO
Cr₂O₇²⁻ + Cl⁻ → CrO₄²⁻ + IO₃⁻ + Cl⁻
CN⁻ + Cu[NH₃]₃⁴⁺ → Cu(CN)₂⁺ + NH₃ + CNO⁻