Solutions to the Extra Problems for Chapter 12

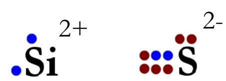
1. The oxidation state of Si is 2+, while the oxidation state of S is 2-. The definition of oxidation state says that in a molecule, it is the charge the atom would have if all shared electrons were given to the most electronegative atom. Thus, we need to construct the Lewis structure of this molecule. We start with Si and S:

When we attach them we get:

Sharing one of each atom's unpaired electrons will give sulfur its ideal electron configuration:

To get silicon what it needs (two more electrons), we will have to make sulfur share one of its electron pairs:

Based on the rules of electronegativity (it increases as you move up and to the right on the Periodic Table), S is more electronegative than Si, because it is in the same row as Si but two columns to the right. As a result, it gets both shared electrons:



Since Si now has two less valence electrons than normal, it has a charge of 2+, while S has two more valence electrons than normal, so its charge is 2-.

2. a. The oxidation state of H is 1+. The oxidation state of Cl is 5+. The oxidation state of O is 2-. This is a covalent compound, and in covalent compounds hydrogen is H^{+}. That means the oxidation state of H is 1+. We don't know about Cl, but oxygen is usually 2-. Summing up what we have so far, the three oxygens give us 6-, and the hydrogen gives us 1+, for a total of 5-. There is no charge on the molecule (it would be written as a superscript if there were), so to make the oxidation states add to 0, the oxidation state of Cl must be 5+.

b. The oxidation state of P is 0. This has only one element in the compound, and the overall charge is 0, so the oxidation state of the element must be 0.

c. The oxidation state of Na is 1+, and the oxidation state of S is 2-. This is an ionic compound, and in those compounds, sodium is Na^{+}. This makes its oxidation state 1+. Since there are two, we have 2+ from the Na's. The overall charge of the compound is zero, so S must be 2-.

d. The oxidation state of S is 6+, and the oxidation state of O is 2-. We can usually count on oxygen to be 2-. There are four of them, so that gives us a total of 8-. The overall charge is 2-, so sulfur must be 6+.

e. The oxidation state of calcium is 2+. The oxidation state of O is 2-. The oxidation state of C is 4+. This is an ionic compound, and in those compounds, calcium is Ca^{2+}, which tells us the oxidation state of calcium is 2+. We can assume that the oxidation state of O is 2-. We therefore have a total of 4- from the oxygens and the calciums. For the entire compound to have no charge, then, C must be 4+.

f. The oxidation state of F is 1-, and the oxidation state of Br is 1+. We know that the oxidation state of F is 1-. Since the sum of the oxidation states must add up to 0, that means the oxidation state of Br is 1+.

g. The oxidation state of K is 1+, the oxidation state of N is 3+, and the oxidation state of O is 2-. This is an ionic compound, and in those compounds, potassium is K^{+}. The oxidation state of oxygen is usually 2-, so the total from the K and the O's is 3-. To make the charge add to zero, that means N must be 3+.

h. The oxidation state of H is 1+, and the oxidation state of S is 2-. The oxidation state of H is 1+ in covalent compounds. The total of the oxidation states must add up to the overall charge, which is zero. Since the two H's give us 2+, the oxidation state of S must be 2-.

3. a. This is a redox reaction. O was reduced, which means O_2 is the oxidizing agent. Sr was oxidized, which makes Sr the reducing agent. The Sr has an oxidation state of 0 on the reactants side. So does the O. On the products side, O is 2-, and Sr is 2+. Since O went from 0 to 2-, it gained electrons, which is why it was reduced. Since Sr went from 0 to 2+, it lost electrons, which is why it was oxidized.

b. This is a redox reaction. S was reduced, which means H_2SO_4 is the oxidizing agent. C was oxidized, which makes C the reducing agent. On the reactants side, C has an oxidation state of 0. The H is 1+, the O is 2-, which makes the S 6+. On the products side, O is 2-, which makes C 4+ and S 4+. The H is still 1+. That means S went from 6+ to 4+, so it gained electrons and was therefore reduced. Since C went from 0 to 4+, it lost electrons and was therefore oxidized.

c. This is a redox reaction. N was reduced, which means HNO_3 is the oxidizing agent. I was oxidized, which makes HI the reducing agent. On the reactants side, H is 1+, and O is 2-. That makes N 5+ and I 1-. On the products side, O is 2-, which makes N 2+. I is zero, and H is still 1+. Since N went from 5+ to 2+, it gained electrons and was therefore reduced. Since I went from 1- to 0, it lost electrons and was therefore oxidized.

d. This is not a redox reaction. On the reactants side, K is 1+, and Br is 1-. Mg is 2+, O is 2-, which makes N 5+. On the products side, the oxidation states are the same for each element.

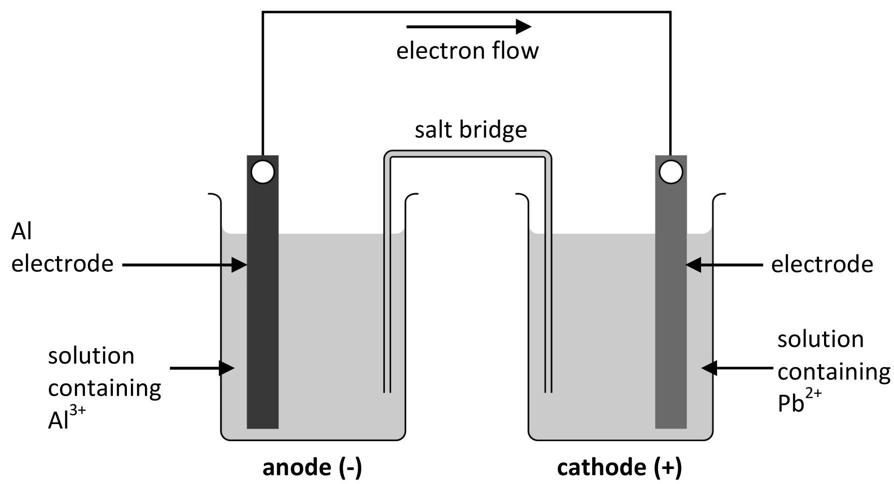
e. This is a redox reaction. Sb was oxidized, which makes it the reducing agent. N was reduced, which makes HNO_3 the oxidizing agent. On the reactants side, Sb is 0. H is 1+, and O is 2-, which makes N 5+. On the products side, O is 2-, which makes Sb 3+ and N 2+. H is still 1+. Since Sb went from 0 to 3+, it lost electrons and was therefore oxidized. Since N went from 5+ to 2+, it gained electrons and was therefore reduced.

4. a. It is the anode. The Cu is losing electrons, so that means electrons are coming from it. Thus, it must be the anode, because the anode is the negative side of the cell.

b. Electrons are flowing away from this side of the cell, since the Cu is losing electrons.

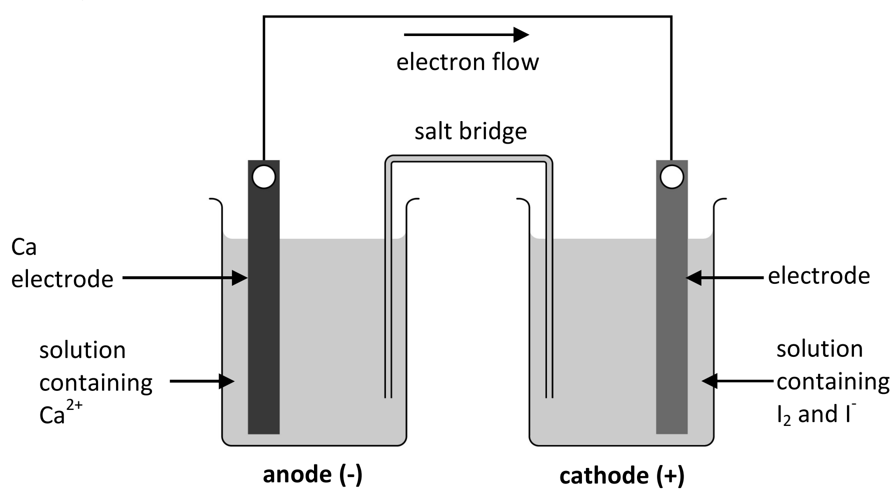
c. Negative ions flow to this side of the cell. This side of the cell is losing electrons. As a result, it would tend to become more and more positive. To counteract this, negative ions in the salt bridge flow towards this side of the cell.

5. a. Al goes from an oxidation state of 0 on the reactants side to an oxidation state of 3+ on the products side. That means it lost electrons and was therefore oxidized. That must happen at the anode, since the anode is the source of electrons, and the electrons come from whatever lost them. Pb went from 2+ to 0, so it was reduced, making it the cathode, which is the side to which the electrons travel so they can be gained. This makes the diagram:



You have to list the element for the anode. The cathode can be any metal, including lead.

b. The I's go from 0 to 1-, so they are reduced. That means they gain electrons and are therefore at the cathode. The Ca's go from 0 to 2+, so they are oxidized. That means they lose electrons, so they are at the anode.



6. a. The balanced equation is Co^{2+} (aq) + $2Ce^{3+}$ (aq) $\rightarrow$ $2Ce^{4+}$ (aq) + Co (s). In this reaction, the atoms are balanced, so we only have to deal with charges. The Co^{2+} becomes Co, so it gains two electrons. The Ce^{3+} becomes Ce^{4+}, so it loses one electron. To balance the electrons, then, I need two Ce's:

$$Co^{2+}\,(aq) + \mathbf{2}Ce^{3+}\,(aq) \rightarrow \mathbf{2}Ce^{4+}\,(aq) + Co\,(s)$$

Now the total charge on both sides is 8+, so it is balanced.

b. The equation is 3Pb + $2Au^{3+}$ $\rightarrow$ 2Au + $3Pb^{2+}$. The atoms are all balanced here, but the charge is not. In order to balance the charge, we need to think about the electrons. Pb went from 0 to 2+, so it lost two electrons. Au went from 3+ to 0, so it gained three electrons. The electrons have to work out, so we need to find the least common multiple between 2 and 3, which is six. So we have to multiply things so there are six electrons. That means there must be three Pb's losing electrons, and two Au's gaining them:

$$\mathbf{3}Pb + \mathbf{2}Au^{3+} \rightarrow \mathbf{2}Au + \mathbf{3}Pb^{2+}$$

Notice that the charge on the reactants side is 6+, while the charge on the products side is also 6+. Since all the atoms are balanced as well, we have a balanced equation.