B2 · Oxidation numbers and redox changes

Student notes - follow the slides, fill the blanks, work the questions

Goals: Find an oxidation number with the rules and the sum rule. Use oxidation numbers to find what is oxidized and what is reduced. Name both agents, and recognize disproportionation.

Name: _____ Date: _____

Slide 1 of 15 · A model for shared electrons

Charge equals the number of protons _____ the number of electrons. Na^+ has 11 protons and 10 electrons, so its charge is _____.

For a one-atom ion, the oxidation number equals the _____. It tells how many electrons the atom gained or lost compared with the neutral atom.

In HCl, chlorine pulls the shared pair harder. This is greater _____. We give both bonding electrons to chlorine, so H is +1 and Cl is _____.

If an atom's oxidation number goes _____, it is oxidized. If it goes _____, it is reduced. This works even when both numbers are positive, such as +5 to +2.

Example. H_2 and HCl are molecules that share electrons. Chlorine is more electronegative than hydrogen. Find the oxidation number of each atom in H_2 and in HCl.

Work:

Answer: _____

Try it. A magnesium ion Mg^{2+} has 12 protons and 10 electrons. What is its charge, and what is its oxidation number?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 2 of 15 · Read the formula before assigning values

A small lower number, called a _____, counts atoms in one particle. No subscript means the count is _____.

A big number in front, called a _____, counts copies of the whole formula. In $2SO_4^{2-}$ there are _____ sulfate ions.

Brackets keep a group together. In $Ca(ClO_4)_2$ the 2 outside multiplies every atom inside, so there are _____ Cl and _____ O but only 1 Ca.

An ion charge is written _____, as in 2−. An oxidation number is written _____, as in +6.

Example. Compare $2SO_4^{2-}$ and $Ca(ClO_4)_2$. For each, give the number of atoms of every element and say what charge the formula carries.

Work:

Answer: _____

Try it. Count the atoms of each element in $Al_2(SO_4)_3$ and give its total charge.

Work:

Answer: _____

Slide 3 of 15 · Rules that fix the known values

An element by itself, such as Cl_2 or Na, has an oxidation number of _____. Check this before any compound rule.

A monatomic ion has an oxidation number equal to its _____. For example, Al^{3+} is _____.

In compounds, Group 1 metals are usually _____ and Group 2 metals are _____. Oxygen is usually _____, hydrogen is usually +1 and fluorine is always _____.

The oxidation numbers of all atoms must add up to the _____.

Example. Given Cl_2, Al^{3+} and MgO. Use the rules to find the oxidation number of every atom without doing any algebra.

Work:

Answer: _____

Try it. Given Na, Cl^- and CaF_2. Assign an oxidation number to every atom using the rules in order.

Work:

Answer: _____

Slide 4 of 15 · Oxidation-number rules · reference

Check the rules in order: an element by itself is _____, a one-atom ion equals its _____, then the compound rules.

Hydrogen is usually _____, but it is −1 in a metal _____.

Oxygen is usually −2, but it is _____ in a peroxide. It can be positive when bonded to _____.

The sum of all atom values is _____ for a neutral compound. For a polyatomic ion the sum is the _____.

Example. Use the rules in order to find the oxidation number of every atom in K_2O. Name the rule you used for each value.

Work:

Answer: _____

Try it. Use the rules to find the oxidation number of every atom in CaH_2. Name the rule you used for hydrogen.

Work:

Answer: _____

Slide 5 of 15 · Start with neutral compounds

In KCl, potassium is +1 and chlorine is _____, so the sum is _____. Chlorine is 0 only when it is an element by itself, as in Cl_2.

In CO, oxygen is −2. Let x be carbon. Then x + (−2) = 0, so carbon is _____.

In NH_3, three hydrogens give 3(+1) = _____. The total must be 0, so nitrogen is _____.

A subscript is an atom _____. It multiplies the value. It does not change the oxidation number of one atom.

Example. Find the oxidation number of every atom in KCl, CO and NH_3. Start with a known rule, then use the total charge of the formula.

Work:

Answer: _____

Try it. Find the oxidation number of nitrogen in NO and of sulfur in H_2S.

Work:

Answer: _____

Slide 6 of 15 · A complete example: sulfur in sulfate

The 2− on SO_4^{2-} belongs to the _____. It is the target total, _____. It is not the value for sulfur or for each oxygen.

Four oxygens at −2 give 4(−2) = _____. Let x be sulfur. Then x + 4(−2) = −2, so x = _____.

Check by putting the answer back: +6 + 4(−2) = _____. The +6 belongs to sulfur alone. The 2− is the charge of the whole _____.

For NH_4^+ the target is _____, not zero. So x + 4(+1) = +1 and nitrogen is _____.

Example. Given the sulfate ion SO_4^{2-}. Find the oxidation number of sulfur and show the counting.

Work:

Answer: _____

Try it. Given the ammonium ion NH_4^+. Find the oxidation number of nitrogen. The ion has one N and four H.

Work:

Answer: _____

Slide 7 of 15 · Method: how to find an oxidation number

Step 1. Write the formula and its overall _____. A neutral compound is _____.

Step 2. Write the _____ values from the rules, such as O usually −2 and H usually +1.

Step 3. Let _____ stand for the unknown atom.

Step 4. Set the _____ of all the oxidation numbers equal to the overall charge.

Step 5. _____ for x and include the sign.

Check: add the numbers again. The total must equal the _____.

Example. Use the method on SO_4^{2-}. Find the oxidation number of sulfur.

Work:

Answer: _____

Try it. Use the method on NO_3^-. Find the oxidation number of nitrogen.

Work:

Answer: _____

Slide 8 of 15 · When the unknown element appears twice

$H_2P_2O_7^{2-}$ has 2 H, 2 P and 7 O, and its charge is _____. The hydrogens give _____ and the oxygens give $7(-2) = -14$.

The known atoms give $+2 - 14 = -12$. The ion must total -2, so the two phosphorus atoms must give _____ together.

Write 2x for two phosphorus atoms: $2(+1) + 2x + 7(-2) = -2$. Then $2x = 10$ and $x =$ _____.

The question asks for one atom, so divide by the _____ at the end. The answer is an _____ value for phosphorus.

Example. Given the ion $H_2P_2O_7^{2-}$. Find the average oxidation number of phosphorus and check the total for the whole ion.

Work:

Answer: _____

Try it. Given the thiosulfate ion $S_2O_3^{2-}$. Find the average oxidation number of sulfur.

Work:

Answer: _____

Slide 9 of 15 · Brackets change the counts, not the method

In $Ca(ClO_4)_2$ the 2 outside the brackets multiplies every atom inside. There is 1 Ca, _____ Cl and _____ O.

Calcium is +2 and oxygen is −2. The formula has no charge, so the total is _____.

The sum is $+2 + 2x + 8(-2) = 0$. Then $2x = 14$, so chlorine is _____. The +14 is the total for two atoms, not the answer.

Check one ClO_4 group: $+7 + 4(-2) =$ _____. Two such groups give −2, which balances the +2 of calcium.

Example. Given the compound $Ca(ClO_4)_2$. Find the oxidation number of chlorine. Show how the outside 2 affects every atom in the brackets.

Work:

Answer: _____

Try it. Given the compound $Mg(NO_3)_2$. Find the oxidation number of nitrogen. Count the atoms first.

Work:

Answer: _____

Slide 10 of 15 · Your turn: nitrate

Start by counting atoms. NO_3^- has _____ oxygens, and each oxygen is _____.

The target total is the ion charge, _____, not zero.

Write one equation with x for nitrogen: $x + 3(-2) = -1$, so $x =$ _____.

Check by putting the answer back: $+5 - 6 =$ _____. If you wrote $x - 6 = 0$, the _____ was wrong. If you wrote $x - 2 = -1$, two _____ were missing.

Example. Given the nitrate ion NO_3^-. Find the oxidation number of nitrogen. Write your sum with signs.

Work:

Answer: _____

Try it. Given the carbonate ion CO_3^{2-}. Find the oxidation number of carbon. Write your sum with signs.

Work:

Answer: _____

Slide 11 of 15 · Exceptions and what an average means

In a peroxide such as H_2O_2, each oxygen is _____. With H at +1, 2(+1) + 2x = 0.

In a metal hydride such as NaH, sodium is +1, so hydrogen is _____.

Fluorine is always _____, so in OF_2 oxygen is _____. Assign fluorine first, then oxygen.

When the sum gives a fraction, as in C_3H_8 where 3x + 8 = 0, x is _____. This is an _____, so do not round it away.

Example. Compare H_2O_2, NaH and OF_2. Find the oxidation number of oxygen in H_2O_2 and OF_2 and of hydrogen in NaH. Say which usual rule changes each time.

Work:

Answer: _____

Try it. BaO_2 is a peroxide. Find the oxidation number of oxygen in BaO_2 and the average oxidation number of carbon in C_4H_{10}.

Work:

Answer: _____

Slide 12 of 15 · A covalent reaction is still redox

In CH_4, four H at +1 total +4, so carbon is _____. In CO_2, two O at −2 total −4, so carbon is _____.

Carbon goes from −4 to +4, an increase of _____, so carbon is _____. Each oxygen atom goes from 0 to −2, so oxygen is reduced.

The balanced equation has $2O_2$, which is 4 O atoms. Four atoms each gaining 2 give _____ electrons gained, which matches the carbon loss.

Name the agent as a whole reactant. CH_4 is the _____ agent and O_2 is the _____ agent.

Example. Given $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$. Identify the oxidized element, the reduced element and both reactant agents.

Work:

Answer: _____

Try it. Given $S(s) + O_2(g) \rightarrow SO_2(g)$. Find the oxidation numbers, the electrons lost and gained, and both agents.

Work:

Answer: _____

Slide 13 of 15 · Method: how to find what was oxidized and reduced

Step 1. _____ every atom on both sides of the equation.

Step 2. _____ each element before and after.

Step 3. If the number goes _____, the particle is oxidized.

Step 4. If the number goes _____, the particle is reduced.

Step 5. Count the _____ for each change and check they match.

Check: the electrons _____ must equal the electrons _____.

Example. Use the method on $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$. Name what is oxidized and what is reduced.

Work:

Answer: _____

Try it. Use the method on $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$. Name what is oxidized and what is reduced.

Work:

Answer: _____

Slide 14 of 15 · Your turn: hydrogen and oxygen

In H_2 and O_2 each atom is _____, because each is an element by itself.

In water, hydrogen is _____ and oxygen is _____.

Coefficients count whole molecules. $2H_2$ has 4 H atoms, each up by 1, so _____ electrons are lost. O_2 has 2 O atoms, each down by 2, so _____ electrons are gained.

Hydrogen is oxidized, so H_2 is the _____ agent. Oxygen is reduced, so O_2 is the oxidizing agent.

Example. Given $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$. Find the oxidation numbers of H and O before and after, name both agents and count the total electrons transferred.

Work:

Answer: _____

Try it. Given $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$. Assign N and H before and after, name both agents and count the total electrons transferred.

Work:

Answer: _____

Slide 15 of 15 · One reactant can do both jobs

In $2H_2O_2 \rightarrow 2H_2O + O_2$, oxygen is -1 in H_2O_2, _____ in H_2O and _____ in O_2.

Oxygen going to -2 is _____. Oxygen going to 0 is oxidized. Some atoms go each way, so follow both destinations.

One reactant that is both oxidized and reduced shows _____. Here H_2O_2 is both the oxidizing agent and the _____ agent.

If no oxidation number changes, as in $CaCO_3 \rightarrow CaO + CO_2$, the reaction is _____ redox.

Example. Given $2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$. Is this redox? Compare the oxidation number of oxygen in all three species and name the agents.

Work:

Answer: _____

Try it. Given $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$. Is this redox? Find the oxidation numbers of Ca, C and O in every formula and justify your answer.

Work:

Answer: _____

B2 · Practice

Oxidation numbers and redox changes | Questions 1-2 of 7

1. Find the oxidation number of Mn in MnO_4^-. Write the sum of all the oxidation numbers, with signs. Set it equal to the charge of the ion.

Work:

Final answer (with unit): _____

2. Find the oxidation number of Cr in $Cr_2O_7^{2-}$. Explain why x is multiplied by 2 in your sum.

Work:

Final answer (with unit): _____

B2 · Practice

Oxidation numbers and redox changes | Questions 3-4 of 7

3. Find the oxidation number of oxygen in O_2, H_2O_2 and OF_2. Explain why the three values are different.

Work:

Final answer (with unit): _____

4. Given $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$. Name both agents. How many electrons move in total?

Work:

Final answer (with unit): _____

B2 · Practice

Oxidation numbers and redox changes | Questions 5-6 of 7

5. Given $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$. Use oxidation numbers to decide if this is a redox reaction.

Work:

Final answer (with unit): _____

6. Given $2H_2O_2 \rightarrow 2H_2O + O_2$. Which reactant is both agents? Explain.

Work:

Final answer (with unit): _____

B2 · Practice

Oxidation numbers and redox changes | Questions 7-7 of 7

7. Challenge: Given the ions $S_2O_3^{2-}$ and $S_4O_6^{2-}$. Find the average oxidation number of sulfur in each ion. Then say whether sulfur is oxidized or reduced when $S_2O_3^{2-}$ changes to $S_4O_6^{2-}$.

Work:

Final answer (with unit): _____