# B2 · Oxidation numbers and redox changes

Student notes - complete the underlined spaces | Notes 1/3

Find the oxidation number of each atom with the rules and the sum rule. Know the exceptions. Use the numbers to find what is oxidized and reduced.

Name: _____ Date: _____

## 1. Rules and formula counting

### An assigned value, not always a real ion charge

An oxidation number is an _____. It is the charge an atom would have if we gave all the bonding electrons to the more electronegative atom, the one that pulls on bonding electrons harder. Identical atoms share the electrons equally.

In $H_2$ the two atoms are the same, so each H is 0. In HCl, chlorine pulls harder, so Cl is -1 and H is +1. This is a counting method, not a measurement. HCl gas does not contain separate $H^+$ and $Cl^-$ ions.

An element by itself has oxidation number _____, including $O_2$ and $F_2$. A one-atom ion, called a monatomic ion, has oxidation number equal to _____. For $Na^+$: 11 protons - 10 electrons = +1.

On the diploma: $Cl_2$ is 0, not -1, because it is an element by itself. Giving it the usual compound value is a common wrong option.

Watch: The oxidation number rules (Tyler DeWitt, “How to Calculate Oxidation Numbers Introduction”, 0:26)

Watch: An element by itself is 0 (Tyler DeWitt, “How to Calculate Oxidation Numbers Introduction”, 0:58)

Watch: A one-atom ion equals its charge (Tyler DeWitt, “How to Calculate Oxidation Numbers Introduction”, 1:47)

### Keep the rule set together

Check the free-element and one-atom-ion cases first. Then use the compound rules. In compounds, Group 1 is _____, Group 2 is _____, and F is _____. Other halogens are usually _____, but Cl, Br and I can be positive when combined with O or F.

H is usually _____, but it is _____ in metal hydrides such as NaH. O is usually _____, but it is _____ in peroxides and can be positive with fluorine. These are usual values, so check each formula for an exception.

The oxidation numbers of all atoms must add up to the charge of the whole formula. A neutral compound has sum _____. A polyatomic ion, a charged group of bonded atoms, has sum equal to _____. A subscript multiplies an atom’s value, but a coefficient in front does not change it.

On the diploma: write oxidation numbers with the sign first, such as +6. Numerical-response answers record only the digits asked for, so read how to enter the sign.

Watch: Group 1A, group 2A and the halogens (Tyler DeWitt, “How to Calculate Oxidation Numbers Introduction”, 2:49)

Watch: Hydrogen is −1 with a metal (Tyler DeWitt, “How to Calculate Oxidation Numbers Introduction”, 9:45)

Watch: Oxygen is −1 in a peroxide (Tyler DeWitt, “How to Calculate Oxidation Number Practice Problems”, 9:49)

Watch: Halogens are positive with oxygen (Tyler DeWitt, “How to Calculate Oxidation Numbers Introduction”, 10:36)

Watch: Fluorine is always −1 (Tyler DeWitt, “How to Calculate Oxidation Numbers Introduction”, 11:50)

## Build the sum

CO: oxygen is -2 and CO is neutral, so x + (-2) = 0. That makes carbon _____. We find carbon’s value from its own formula, not from another compound.

$NH_3$: each H is +1, and three H contribute 3 × (+1) = _____. The total must be 0, so nitrogen is _____. The subscript 3 counts atoms. It does not make each H +3.

For the sulfate diagram, label three things: which number is an atom count, which is the whole-ion charge, and which is the per-oxygen value. Then complete the sulfur calculation.

Watch: A neutral compound adds to 0 (Tyler DeWitt, “How to Calculate Oxidation Numbers Introduction”, 3:31)

Watch: Find the unknown: carbon in CO (Tyler DeWitt, “How to Calculate Oxidation Numbers Introduction”, 4:53)

Watch: An ion adds to its charge (Tyler DeWitt, “How to Calculate Oxidation Numbers Introduction”, 7:45)

Watch: Diploma example: sulfur in $H_2SO_3$ (Alberta Chemistry Teacher, “Electrochemistry Diploma Prep - Chemistry 30 - Part 1 of 4”, 12:57)

Given $SO_4^{2-}$; let sulfur = x.

O atom count: _____ Whole-ion charge: _____

Each O: _____ All O total: _____

Sum and sulfur: _____

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## 2. Read the formula, then solve step by step

### Read the whole formula first

Before you assign anything, count what is in the formula. In $SO_4^{2-}$ there is _____ S and _____ O. The whole ion has a charge of _____. In $2SO_4^{2-}$ you have two copies, but each ion still has a charge of _____.

Brackets keep a group together. In $Ca(ClO_4)_2$ the 2 outside multiplies _____. So the full count is _____. No charge is written, so the atoms must add up to _____.

On the diploma: count the atoms inside brackets first. Most wrong answers come from forgetting that the outside number multiplies everything inside.

Watch: Multiply by the number of atoms (Tyler DeWitt, “How to Calculate Oxidation Number Practice Problems”, 2:28)

### Two signed values, written two ways

An ion charge is written with the number first, then the sign: $Ca^{2+}$ is _____ and $SO_4^{2-}$ is _____. An oxidation number is written with the sign first, then the number: calcium is _____ and sulfur in sulfate is _____.

The charge belongs to the _____. The oxidation number is a value we assign to _____. Try $NH_4^+$. Hydrogen is +1, so x + 4(+1) = +1. That makes N equal to _____. Check: -3 + 4 = _____, which matches the ion charge.

Watch: Write the sign first for oxidation numbers (Tyler DeWitt, “How to Calculate Oxidation Numbers Introduction”, 2:18)

Watch: Charge and oxidation number: number and sign swap places (Alberta Chemistry Teacher, “Electrochemistry Diploma Prep - Chemistry 30 - Part 1 of 4”, 22:56)

### When the unknown element appears twice

Take $H_2P_2O_7^{2-}$. Hydrogen is +1 and oxygen is -2. The known atoms add to 2(+1) + 7(-2) = _____. The ion must total -2, so the two phosphorus atoms together must supply _____.

Write it as an equation, with x as the value for one P: 2(+1) + 2x + 7(-2) = -2. Solve it: 2x = _____, so x = _____. Check: +2 + 2(+5) - 14 = _____.

On the diploma: if the unknown element appears twice, divide your total by two at the end. Then check the sum against the ion charge.

Watch: Two carbons in $CaC_2$ (Tyler DeWitt, “How to Calculate Oxidation Numbers Introduction”, 6:58)

Watch: Two phosphorus atoms (Tyler DeWitt, “How to Calculate Oxidation Number Practice Problems”, 6:11)

## A full worked example, then your turn

Let’s do $Ca(ClO_4)_2$ with Ca as +2 and O as -2. The equation is +2 + 2x + 8(-2) = 0. Solve: 2x = _____, so each Cl is _____. Check: +2 + 14 - 16 = _____.

Look at one $ClO_4^-$ group on its own: +7 + 4(-2) = _____. Two of those groups balance one $Ca^{2+}$, so the Cl value stays the same in each group.

Your turn with $Al_2(SO_4)_3$. Take Al as +3 and O as -2. Count first: two Al, _____ and _____. Then 2(+3) + 3x + 12(-2) = 0, so each S is _____. Check: +6 + 18 - 24 = _____.

Watch: A formula with brackets: $Ca(ClO_4)_2$ (Tyler DeWitt, “How to Calculate Oxidation Number Practice Problems”, 12:55)

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## 3. Exceptions, averages and reaction changes

### Model and check

In $SO_4^{2-}$ the target is the charge printed on the ion, -2. So x + 4(-2) = -2, and sulfur is _____. Check: +6 - 8 = _____. The +6 belongs to sulfur alone. Sulfate does not contain a free $S^{6+}$ ion.

$H_2O_2$: with H at +1, 2(+1) + 2x = 0 gives O = _____. NaH: +1 + x = 0 gives H = _____. $OF_2$: F is -1, so x + 2(-1) = 0 gives O = _____. Give fluorine its value first. The sum rule still works when a usual value changes.

In $C_3H_8$ the eight H at +1 give +8, so 3x + 8(+1) = 0. Average carbon is _____. This is an average, not a real fractional charge, so do not round it away.

On the diploma: wrong options are often built from a wrong target. Use the printed ion charge, never zero, for an ion such as sulfate.

Watch: An ion: $CO_3^{2-}$ (Tyler DeWitt, “How to Calculate Oxidation Number Practice Problems”, 4:37)

### Compare reactants with products

An increase in oxidation number means _____. A decrease means _____. This works even when both numbers are positive, such as +5 to +2. In $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$, carbon changes _____ and oxygen changes _____.

Check that the counting balances. Carbon rises by 8. Four oxygen atoms each fall by 2, and 4 × 2 = 8. So the electrons lost equal the electrons gained.

The reducing agent is the whole starting substance _____. The oxidizing agent is _____. Find the changing element, then go back to its reactant formula. Naming the element or a product is a common wrong choice.

In $2H_2O_2 \rightarrow 2H_2O + O_2$, oxygen starts at -1 and ends at _____. The same reactant is both oxidized and reduced. This is _____. Some peroxide oxygen goes down to water and some goes up to $O_2$.

On the diploma: to call a reaction "not redox", say that no oxidation number changes.

Watch: Number goes up is oxidation, down is reduction (Tyler DeWitt, “Oxidizing Agents and Reducing Agents”, 6:13)

Watch: Diploma example: what is oxidized in aluminium and chlorine (Alberta Chemistry Teacher, “Electrochemistry Diploma Prep - Chemistry 30 - Part 1 of 4”, 2:47)

Watch: Diploma example: oxidation numbers in a combustion reaction (Alberta Chemistry Teacher, “Electrochemistry Diploma Prep - Chemistry 30 - Part 1 of 4”, 8:32)

# B2 · Practice

Oxidation numbers and redox changes | Questions 1-3 of 12

State symbols: (s) solid, (aq) dissolved in water, (l) liquid, (g) gas. Use the supplied reaction and conditions. B4 values name the Alberta Chemistry 30 Data Booklet table where used.

B2-P01 · Easy · Find the oxidation numbers of Mg(s), $O_2$(g), $Fe^{3+}$(aq) and $Cl^-$(aq). Say which rule you used for each one.

B2-P02 · Easy · Find the oxidation numbers of K and Cl in KCl. Show that they add up to the charge of the formula.

B2-P03 · Easy · Find the oxidation number of carbon in $CO_2$. Show how the subscript on oxygen is used in the sum.

# B2 · Practice

Oxidation numbers and redox changes | Questions 4-6 of 12

B2-P04 · Easy · Find the oxidation number of nitrogen in $NH_3$. Give the value for one H, and the total for all the H atoms.

B2-P05 · Medium · Find the oxidation number of sulfur in $SO_3^{2-}$. Write the total the numbers must add to before you solve. Then check your answer.

Optional start: Circle the charge on the whole ion before you write the sum.

B2-P06 · Medium · Find the oxidation number of nitrogen in $NO_3^-$ and then in $NO_2^-$. If nitrate changes to nitrite, is nitrogen oxidized or reduced?

# B2 · Practice

Oxidation numbers and redox changes | Questions 7-9 of 12

B2-P07 · Medium · Find the oxidation number of oxygen in $H_2O_2$ and in $OF_2$. Say why the usual value for oxygen does not work in each one.

B2-P08 · Medium · Find the oxidation number of hydrogen in $CaH_2$. Then find the oxidation number of bromine in $BrO_3^-$. Show both sums.

B2-P09 · Challenging · For $C_2H_6 + 7/2\ O_2 \rightarrow 2CO_2 + 3H_2O$, find the average oxidation number of carbon on each side. What is oxidized and what is reduced? Name both agents. How many electrons does each $C_2H_6$ lose?

# B2 · Practice

Oxidation numbers and redox changes | Questions 10-12 of 12

B2-P10 · Challenging · A student solves $NO_3^-$ with x + 3(-2) = 0 and gets +6. Find the mistake and fix the sum. Explain why checking the arithmetic alone would not find the mistake.

B2-P11 · Challenging · For $2H_2O_2 \rightarrow 2H_2O + O_2$, find the oxidation number of oxygen in all three substances. Explain why $H_2O_2$ is both agents. Explain why having two products does not prove disproportionation.

B2-P12 · Challenging · Find the average oxidation number of carbon in $C_2H_6O$. A student says the answer is the real charge on each carbon atom. Explain what the calculation shows and what it does not show.