B1 · Electron transfer and redox

Completed notes

Goals: Explain oxidation and reduction as electrons lost and gained. Name what is oxidized, what is reduced, and both agents. Tell a redox reaction from ions that only separate.

Slide 1 of 12 · One electron transfer has two sides

In a redox reaction, an electron moves from one particle to another. Redox is short for **oxidation–reduction**.

Oxidation means **loss** of electrons. The particle that loses the electron is **oxidized**.

Reduction means **gain** of electrons. The particle that gains the electron is **reduced**.

Oxidation and reduction always happen **together**, because the electron that one particle loses is the same electron the other particle **gains**.

Example. A particle model shows one electron moving from atom A to atom B. What happens to each atom? Use the words oxidized and reduced.

1. Atom A loses the electron, so A is oxidized.

2. Atom B gains the electron, so B is reduced.

3. It is one event seen from two ends.

Try it. An electron moves from particle X to particle Y. Which particle is oxidized, which is reduced, and how many electrons moved?

1. X lost the electron, so X is oxidized.

2. Y gained the electron, so Y is reduced.

3. One electron moved.

Slide 2 of 12 · Why gaining electrons reduces charge

A neutral atom has protons, which are **positive**, and electrons, which are **negative**. Their charges cancel, so the total is **0**.

One electron has a charge of **−1**. Gaining an electron adds a negative amount, so the total charge goes **down**. That is why gaining electrons is called **reduction**.

Losing an electron removes a negative amount, so the total charge goes **up**. A neutral atom that loses one electron becomes **1+**.

OIL RIG: Oxidation Is **Loss** of electrons; Reduction Is **Gain** of electrons.

Example. An ion with charge 3+ gains one electron. What is its new charge, and is it oxidized or reduced?

1. The new charge is $+3 + (-1) = +2$, which is 2+.

2. It gained an electron, so it is reduced.

3. The ion is still positive, but its charge went down.

Try it. A neutral atom loses two electrons. What is its new charge, and is it oxidized or reduced?

1. Removing two negative electrons raises the charge: $0 - (-2) = +2$, which is 2+.

2. It lost electrons, so it is oxidized.

Slide 3 of 12 · Read particles, formulas and states

An **atom** has a nucleus and electrons. An **ion** is a particle with a charge, because its positive and negative charges do not balance.

A big number in front of a formula counts **copies**: 2Na means two sodium atoms. A small lower number counts **atoms** inside one formula: Cl_2 has two chlorine atoms.

The letters in brackets give the state: (s) is **solid**, (l) is **liquid**, (g) is **gas** and (aq) means **dissolved in water**.

In the shell model, Na is 2,8,1. Each number is the electrons in one shell. The last number is the **valence** electrons, which sit in the outer shell.

Example. Given $2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$. How many sodium atoms and how many chlorine atoms are on the left side?

1. 2Na means 2 sodium atoms.

2. Cl_2 has 2 chlorine atoms in one molecule.

3. So the left side has 2 sodium atoms and 2 chlorine atoms.

Try it. Chlorine is 2,8,7. How many valence electrons does it have, and what ion forms if it gains one electron?

1. The last number is 7, so chlorine has 7 valence electrons.

2. Gaining one electron gives 2,8,8 and a charge of 1−, so the ion is Cl^-.

Slide 4 of 12 · Sodium chloride: before, transfer, after

Sodium metal is made of **neutral** Na atoms. Chlorine gas is made of neutral Cl_2 **molecules**. Neither one contains ions.

In the reaction $2Na + Cl_2 \rightarrow 2NaCl$, each sodium atom gives up **1** electron and becomes Na^+. Each chlorine atom gains **1** electron and becomes Cl^-.

Two sodium atoms lose 2 electrons and two chlorine atoms gain 2 electrons. The electrons lost **equal** the electrons gained.

Opposite charges **attract**, so the ions pull together into a repeating pattern called a **lattice**. The solid is neutral overall.

Example. Given $2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$. How do the neutral starting atoms become the ions in the solid?

1. Each sodium atom gives one electron to a chlorine atom.

2. Each sodium atom becomes Na^+ and each chlorine atom becomes Cl^-.

3. Opposite charges attract, so the ions form the NaCl lattice.

Try it. How many sodium ions and how many chloride ions are in the product of $2Na + Cl_2 \rightarrow 2NaCl$, and what is the total charge of the product?

1. There are 2 Na^+ ions and 2 Cl^- ions.

2. The total charge is $2(+1) + 2(-1) = 0$, so the solid is neutral.

Slide 5 of 12 · Name what happens to each reactant

Look at each reactant separately. Sodium goes from neutral Na to **Na^+**. An electron leaves sodium, so sodium is **oxidized**.

Chlorine goes from neutral Cl_2 to **$2Cl^-$**. Electrons enter chlorine, so chlorine is **reduced**.

Oxidation and reduction always happen **together**: one cannot happen without the other.

In $2Na + Cl_2 \rightarrow 2NaCl$, the **2** electrons lost equal the **2** electrons gained.

Example. Use the sodium and chlorine reaction. Which reactant is oxidized, and which is reduced?

1. Sodium loses an electron and becomes Na^+, so sodium is oxidized.

2. Chlorine gains electrons and becomes Cl^-, so chlorine is reduced.

Try it. In $2Na + Cl_2 \rightarrow 2NaCl$, how many electrons are lost in total, and how many are gained in total?

1. Two sodium atoms each lose 1 electron, so 2 electrons are lost.

2. Two chlorine atoms each gain 1 electron, so 2 electrons are gained.

Slide 6 of 12 · Write the two halves of the story

A half-reaction shows only one half of the electron transfer. The symbol e^- is **one electron**.

In a reduction half-reaction the electrons are on the **left** (reactant) side: $Cl_2 + 2e^- \rightarrow \mathbf{2Cl^-}$.

In an oxidation half-reaction the electrons are on the **right** (product) side: $2Na \rightarrow 2Na^+ + \mathbf{2e^-}$.

Add the two halves and cancel the **electrons**, because they appear on opposite sides: $2Na + Cl_2 \rightarrow 2Na^+ + 2Cl^-$.

Example. Write the reduction half-reaction for Cl_2 forming Cl^-, and the oxidation half-reaction for Na forming Na^+, using the equation $2Na + Cl_2 \rightarrow 2Na^+ + 2Cl^-$.

1. Reduction: $Cl_2(g) + 2e^- \rightarrow 2Cl^-$

2. Oxidation: $2Na(s) \rightarrow 2Na^+ + 2e^-$

3. Add them. The $2e^-$ cancel, leaving $2Na + Cl_2 \rightarrow 2Na^+ + 2Cl^-$.

Try it. Write the oxidation half-reaction for one zinc atom forming Zn^{2+}. Where do the electrons go in the equation?

1. $Zn(s) \rightarrow Zn^{2+} + 2e^-$

2. The electrons are on the product side, because oxidation releases electrons.

Slide 7 of 12 · An agent is named for its effect on the partner

An oxidizing agent **causes** oxidation of the other reactant. It does this by **gaining** electrons, so the oxidizing agent is itself reduced.

A reducing agent causes **reduction** of the other reactant. It does this by **giving** electrons, so the reducing agent is itself oxidized.

There are two names for each reactant. Its own change is oxidized or reduced. Its effect on the **partner** is the agent name.

In $2Na + Cl_2 \rightarrow 2NaCl$, sodium is oxidized, so sodium is the **reducing** agent. Chlorine is reduced, so chlorine is the **oxidizing** agent.

Example. Sodium gives electrons and chlorine receives them. Why is sodium called the reducing agent even though it is oxidized?

1. The agent name describes the effect on the partner.

2. Sodium gives electrons to chlorine, so it causes chlorine to be reduced.

3. So sodium is the reducing agent, and sodium itself is oxidized.

Try it. In $2Na + Cl_2 \rightarrow 2NaCl$, name the oxidizing agent and say what it does to the other reactant.

1. Chlorine is the oxidizing agent.

2. It takes electrons from sodium, so it causes sodium to be oxidized.

Slide 8 of 12 · Method: how to name an electron transfer

Step 1. Write the **change** for each particle, from start to end.

Step 2. Find the **loser**. The particle that loses electrons is **oxidized**.

Step 3. Find the **gainer**. The particle that gains electrons is **reduced**.

Step 4. Name the agents. The oxidizing agent is what is **reduced**. The reducing agent is what is **oxidized**.

Step 5. Write two **halves**. Electrons are on the product side for oxidation and on the reactant side for reduction.

Check: the electrons **lost** must equal the electrons **gained**.

Example. Use the method on $2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$. Name the electron transfer, the agents and the two halves.

1. Step 1: Na goes from 0 to +1. Cl goes from 0 to −1.

2. Steps 2 and 3: sodium loses electrons, so it is oxidized. Chlorine gains electrons, so it is reduced.

3. Step 4: the oxidizing agent is Cl_2. The reducing agent is Na.

4. Step 5: $Na \rightarrow Na^+ + e^-$ and $Cl_2 + 2e^- \rightarrow 2Cl^-$. Two electrons are lost per two Na and two are gained.

Try it. Use the method on $Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$. Name what is oxidized, what is reduced and the oxidizing agent.

1. Mg goes from 0 to +2, so Mg is oxidized and is the reducing agent.

2. Cl goes from 0 to −1, so Cl_2 is reduced and is the oxidizing agent.

3. Two electrons are lost by Mg and two are gained by Cl_2.

Slide 9 of 12 · Ions present does not mean electrons transferred

Forming NaCl from its elements is a **redox** reaction. Neutral Na and Cl_2 change into ions by electron **transfer**.

Dissolving NaCl in water is different. The solid already contains **Na^+ and Cl^-**, and the dissolved ions are the same ions.

In dissolving, ions **separate**, but no electrons are transferred. So dissolving is **not** a redox reaction.

To test for redox, ask whether any particle **gained or lost** electrons.

Example. Compare making NaCl from its elements with dissolving NaCl that already exists. What changes in each process?

1. Making NaCl: neutral elements change into ions by electron transfer. That is redox.

2. Dissolving NaCl: existing ions separate. No electrons are transferred, so it is not redox.

Try it. Given $KNO_3(s) \rightarrow K^+(aq) + NO_3^-(aq)$. Is this redox? Explain in one sentence.

1. No. The ions were already in the solid and they only separate, so no electrons are gained or lost.

Slide 10 of 12 · Same idea, different starting particles

The electron-transfer idea works for any reactants. In $Mg + Cu^{2+} \rightarrow Mg^{2+} + Cu$, the reactants are Mg atoms and **Cu^{2+}** ions.

First decide which reactant **gives** electrons. Mg goes from 0 to 2+, so it loses **2** electrons and is oxidized.

Cu^{2+} goes from 2+ to 0, so it **gains** 2 electrons and is reduced.

The agents follow: Mg is the **reducing** agent and Cu^{2+} is the **oxidizing** agent.

Example. Given $Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$. First draw the electron arrow. Then name the changes and both agents.

1. The electron arrow goes from Mg to Cu^{2+} ($2e^-$).

2. Mg is oxidized and is the reducing agent.

3. Cu^{2+} is reduced and is the oxidizing agent.

Try it. Given $Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$. Name what is oxidized, what is reduced and both agents.

1. Zn loses 2 electrons, so Zn is oxidized and is the reducing agent.

2. Cu^{2+} gains 2 electrons, so Cu^{2+} is reduced and is the oxidizing agent.

Slide 11 of 12 · Use an electron record instead of an equation

Sometimes the question gives an electron record, not an equation. Read the electron **count** for each particle.

If a particle keeps its nucleus and its electron count goes **down**, it is oxidized and is the reducing agent.

If its electron count goes **up**, it is reduced and is the **oxidizing** agent.

The electrons lost by one particle **equal** the electrons gained by the other.

Example. A question says: P keeps its nucleus and loses two electrons. Q keeps its nucleus and gains those two electrons. Name both agent roles and explain one.

1. P is oxidized, so P is the reducing agent.

2. Q is reduced, so Q is the oxidizing agent.

3. Explanation: P gives electrons to Q, so P causes Q to be reduced.

Try it. A question says: R keeps its nucleus and its electron count goes from 18 to 15. S gains those electrons. Name what happens to R and S, and the agents.

1. R loses 3 electrons, so R is oxidized and is the reducing agent.

2. S gains 3 electrons, so S is reduced and is the oxidizing agent.

Slide 12 of 12 · Carry the explanation into oxidation numbers

Follow the electron **transfer** first. Loss of electrons is **oxidation**. Gain of electrons is **reduction**.

The agent name describes the effect on the **partner**: the reducing agent is oxidized, and the oxidizing agent is **reduced**.

For simple ions we tracked the actual **charge**.

For molecules, **oxidation numbers** do the same counting. B2 teaches them.

Example. How do electron transfer, charge changes, half-reactions and agent names describe one connected idea? Use Na and Cl_2 in your answer.

1. Na loses electrons, so Na is oxidized and its charge rises from 0 to 1+.

2. Cl_2 gains electrons, so Cl is reduced and its charge falls from 0 to 1−.

3. The half-reactions show each side. The agent names say each reactant causes the other change.

Try it. In one sentence, say which three words describe electron loss, electron gain and the effect on a partner.

1. Loss is oxidation, gain is reduction, and the agent name says what the reactant does to its partner.

B1 · Worked practice

Electron transfer and redox | Questions 1-2 of 7

1. Given: $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$. Is zinc oxidized or reduced? Explain the change in charge.

Zinc is oxidized, because it loses two electrons. Taking away two negative charges makes its charge go up from 0 to 2+. Check the charge: 0 on the left, and $+2 - 2 = 0$ on the right.

2. Given: $2Al(s) + 3Cu^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Cu(s)$. Name both agents. How many electrons move in the reaction as written?

Use Method: how to name an electron transfer. Al is the reducing agent and Cu^{2+} is the oxidizing agent. Each of the two Al atoms loses 3 electrons, so 6 electrons are lost. Each of the three Cu^{2+} ions gains 2 electrons, so 6 electrons are gained. The numbers in front are given, so you do not balance anything.

B1 · Worked practice

Electron transfer and redox | Questions 3-4 of 7

3. Given: $NaNO_3(s) \rightarrow Na^+(aq) + NO_3^-(aq)$. The solid already contains Na^+ and NO_3^- ions. Is this a redox reaction? Explain.

No. The ions were already in the solid, and they only move apart in the water. Na^+ is 1+ before and after, and NO_3^- is 1− before and after. No particle lost or gained electrons.

4. Given: $Sn^{2+}(aq) + 2Fe^{3+}(aq) \rightarrow Sn^{4+}(aq) + 2Fe^{2+}(aq)$. Draw the arrow that shows which way the electrons move. Name both agents.

The arrow goes from Sn^{2+} to Fe^{3+}. Sn^{2+} loses 2 electrons and is oxidized, so it is the reducing agent. Each Fe^{3+} gains 1 electron and is reduced, so Fe^{3+} is the oxidizing agent. Two Fe^{3+} ions gain the 2 electrons that one Sn^{2+} loses. Both agents start as positive ions.

B1 · Worked practice

Electron transfer and redox | Questions 5-6 of 7

5. Given: a particle keeps 12 protons while its number of electrons changes from 10 to 12. Give its charge at the start and at the end. Is it oxidized or reduced?

At the start: 12 − 10 = +2. At the end: 12 − 12 = 0. It gains 2 electrons, so it is reduced. Its protons do not change, so it is still the same element.

6. A student says: “Cu^{2+} becomes Cu, so copper loses its positive charge by losing electrons.” Find the mistake and write the correct statement.

Electrons are negative. Cu^{2+} gains 2 electrons, so its charge goes down from +2 to 0. It is reduced. Losing electrons would make its charge go up, not down.

B1 · Worked practice

Electron transfer and redox | Questions 7-7 of 7

7. Challenge: Given: $Mg(s) + 2Ag^{+}(aq) \rightarrow Mg^{2+}(aq) + 2Ag(s)$. Write the oxidation half-reaction and the reduction half-reaction. Then state how many electrons 3 Mg atoms transfer in total.

Oxidation: $Mg \rightarrow Mg^{2+} + 2e^{-}$. Magnesium loses electrons. Reduction: $2Ag^{+} + 2e^{-} \rightarrow 2Ag$. Silver ions gain them. Each Mg atom loses 2 electrons, so 3 Mg atoms transfer $3 \times 2 = 6$ electrons. Those 6 electrons are gained by 6 Ag^{+} ions.