B3 · Balance redox equations in acid

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

Conserve atoms and charge, match electrons, build acidic halves and verify given basic halves.

Name: _____ Date: _____

1. Two checks and two matching halves

Atoms and charge both have to balance

A balanced equation keeps two things equal on both sides: the count of each _____ and the _____. Electrons carry charge but add _____. Equal charge does not have to mean zero charge.

Take $Al \rightarrow Al^{3+} + 3e^-$. The charge is 0 on the left and +3 - 3 = 0 on the right, so it balances. For $Cu^{2+} + 2e^- \rightarrow Cu$, the left is +2 - 2 = 0. Al gives 3 electrons and Cu takes 2. The smallest number both divide into is _____. So multiply the whole Al half by _____ and the whole Cu half by _____.

Now add the halves: $2Al + 3Cu^{2+} + 6e^- \rightarrow 2Al^{3+} + 6e^- + 3Cu$. Only identical terms on _____ cancel, so the six electrons cancel. The net charge is _____ on each side. Never change a subscript or an ion charge just to make things balance.

On the diploma: check atoms, charge, cancelling and lowest whole-number coefficients, one at a time.

Watch: Why redox balancing checks atoms and charge (Tyler DeWitt, “How to Balance Redox Equations in Acidic Solution”, 0:19)

Start from the full reaction you are given

Say the solution is acidic and you are given $MnO_4^- + Fe^{2+} \rightarrow Mn^{2+} + Fe^{3+}$. Mn goes from _____ in permanganate to +2, which is reduction. Fe goes from +2 to +3, which is _____.

Write the real species in each skeleton: _____ and _____. A +7 oxidation number does not mean a free Mn^{7+} ion exists. It is only a counting tool.

Then balance in this order: other atoms first, then O with _____, then H with _____, then total charge with _____. The solution type and the products are given to you, so do not guess them.

On the diploma: write the species exactly as given. Do not swap in a different ion.

Watch: Give each atom an oxidation number (Tyler DeWitt, “How to Balance Redox Equations in Acidic Solution”, 1:04)

Watch: Which atom is oxidized and which is reduced (Tyler DeWitt, “How to Balance Redox Equations in Acidic Solution”, 4:15)

B3 · Balance redox equations in acid

Student notes - complete the underlined spaces | Notes 2/3

2. Build one acidic half, then combine

Build the permanganate half one step at a time

Start with MnO_4^- → Mn^{2+}. Mn matches, but the left has four O and the right has none. So _____. Add _____ to the right. Four waters also bring in _____ on the right.

Add _____ to the left to match those hydrogens. Now Mn is 1, O is 4 and H is 8 on both sides. Check the charge before adding electrons: the left is -1 + 8 = _____, and the right is _____.

Add _____: +7 - 5 = +2. The finished half is $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$. Making the left side zero would _____, and the charges must match.

As a second check, one Mn goes from +7 to +2. That is _____. It supports the charge result, but it does not replace counting atoms.

On the diploma: write the electrons last, after atoms and charge are checked.

Watch: Balance oxygen with H_2O (Tyler DeWitt, “How to Balance Redox Equations in Acidic Solution”, 6:42)

Watch: Balance hydrogen with H^+ (Tyler DeWitt, “How to Balance Redox Equations in Acidic Solution”, 7:14)

Watch: Balance charge with electrons (Tyler DeWitt, “How to Balance Redox Equations in Acidic Solution”, 8:16)

Combine the two halves

$Fe^{2+} \rightarrow Fe^{3+} + e^-$ releases one electron, but the Mn half takes five. So multiply the iron half by _____. The manganese half stays as it is.

Write every term before cancelling. The left has $MnO_4^- + 8H^+ + 5e^- + 5Fe^{2+}$, and the right has $Mn^{2+} + 4H_2O + 5Fe^{3+} + 5e^-$. Cancel _____.

The net equation is $MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$. The charge is _____ on each side. H^+ and water stay in the equation because they have _____.

On the diploma: only cancel identical terms that sit on opposite sides.

Watch: Make the electrons equal (Tyler DeWitt, “How to Balance Redox Equations in Acidic Solution”, 10:46)

Watch: Add the halves and cancel (Tyler DeWitt, “How to Balance Redox Equations in Acidic Solution”, 11:51)

Acidic: $MnO_4^- + ___ H^+ + ___ e^- \rightarrow Mn^{2+} + ___ H_2O$

Before e^-: left _____; right _____

After e^-: left _____; right _____

Equal signed charge is required; neutral totals are not required.

B3 · Balance redox equations in acid

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

3. Changed sides, new examples and given basic halves

Water does not always go on the right

Try NO_2^- → NO_3^- in acid. The right has one more O, so add _____. That puts two H on the left, so add _____. The charge is now -1 on the left and +1 on the right.

Add _____: $NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e^-$. N goes from +3 to +5, which is _____. H^+ can appear as a product even in acid. Put it on whichever side the atom count needs.

On the diploma: do not assume H_2O is always a product. Check which side is missing oxygen.

Combine, cancel what repeats, then simplify

Combine $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ with $NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e^-$. The smallest shared electron total is _____. So multiply the first half by _____ and the second by _____.

Add the halves and cancel $10e^-$. The left has $16H^+$ and the right has $10H^+$, so _____ is left over on the left. The left has $5H_2O$ and the right has $8H_2O$, so _____ is left over on the right.

The net equation is $2MnO_4^- + 6H^+ + 5NO_2^- \rightarrow 2Mn^{2+} + 3H_2O + 5NO_3^-$. The charge is _____ on each side.

On the diploma: after cancelling electrons, also cancel repeated H^+ and H_2O.

Watch: Cancel what appears on both sides (Tyler DeWitt, “How to Balance Redox Equations in Acidic Solution”, 12:50)

Watch: Divide by a common factor (Tyler DeWitt, “Balance Redox Equations in Acid Example 2 (Advanced)”, 12:24)

Dichromate: a changed attempt

In acid, take $Cr_2O_7^{2-} \rightarrow Cr^{3+}$. First make _____ so the Cr atoms match. The left has seven O, so add _____ on the right. That brings 14 H, so add _____ on the left. The charges are +12 on the left and +6 on the right, so add _____.

Final check: Cr is 2, O is 7, H is 14 and the charge is _____. Each of the two Cr atoms drops by three. That accounts for _____.

Watch: Balance the chromium (Tyler DeWitt, “How to Balance Redox Equations in Acidic Solution Example 1”, 5:40)

Watch: Add 7 H_2O (Tyler DeWitt, “How to Balance Redox Equations in Acidic Solution Example 1”, 6:11)

Watch: Add 14 H^+ (Tyler DeWitt, “How to Balance Redox Equations in Acidic Solution Example 1”, 6:43)

Watch: Add 6 electrons (Tyler DeWitt, “How to Balance Redox Equations in Acidic Solution Example 1”, 8:18)

Combine given basic halves

A neutral solution is built the same way as an acidic one, with H_2O and H^+. Basic half-reactions are _____ to you, not made up by you.

Say you are given $OCl^- + H_2O + 2e^- \rightarrow Cl^- + 2OH^-$ and $2I^- \rightarrow I_2 + 2e^-$. Both halves already use _____, so just cancel them. You get $OCl^- + H_2O + 2I^- \rightarrow Cl^- + 2OH^- + I_2$.

The charge is _____ on each side. Use the basic form you were given. Do not turn it into an acidic one. Also, balancing does not tell you _____. That is the next lesson.

On the diploma: if basic halves are given, only match electrons and cancel.

Watch: Add the halves and cancel (Tyler DeWitt, “How to Balance Redox Equations in Basic Solution”, 10:53)

B3 · Practice

Balance redox equations in acid | 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.

B3-P01 · Easy · Write the balanced oxidation half-reaction for $Mg(s) \rightarrow Mg^{2+}(aq)$. Add the electrons and check the charge.

B3-P02 · Easy · Write the balanced reduction half-reaction for $Fe^{3+}(aq) \rightarrow Fe^{2+}(aq)$. Show the charge on each side.

B3-P03 · Easy · Given $Al \rightarrow Al^{3+} + 3e^{-}$ and $Ag^{+} + e^{-} \rightarrow Ag$. What is the lowest number of electrons that both halves can move? What do you multiply each half by?

B3 · Practice

Balance redox equations in acid | Questions 4-6 of 12

B3-P04 · Easy · Check $Zn + 2Ag^+ \rightarrow Zn^{2+} + 2Ag$. Count each element and add the charge on each side. Is the charge balanced even though it is not zero?

B3-P05 · Medium · Join $Mg \rightarrow Mg^{2+} + 2e^-$ and $Ag^+ + e^- \rightarrow Ag$ into one net ionic equation. Show the half you multiplied and what you cancelled.

Optional start: Make the electrons equal before you add the two halves.

B3-P06 · Medium · In acidic solution, balance $MnO_4^- \rightarrow Mn^{2+}$ with H_2O, H^+ and e^-. Explain why you add them in that order.

B3 · Practice

Balance redox equations in acid | Questions 7-9 of 12

B3-P07 · Medium · In acidic solution, balance $Cr_2O_7^{2-} \rightarrow Cr^{3+}$ as a reduction half-reaction. Check the atoms and the charge.

B3-P08 · Medium · A student writes $MnO_4^- + 8H^+ + 7e^- \rightarrow Mn^{2+} + 4H_2O$. Which check fails? Fix only the number of electrons. Explain why the student may have chosen seven.

B3-P09 · Challenging · In acidic solution, join $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ with $I^- \rightarrow 1/2\ I_2 + e^-$. Write the net equation with the lowest whole numbers. Check the atoms and the charge.

B3 · Practice

Balance redox equations in acid | Questions 10-12 of 12

B3-P10 · Challenging · A question gives three reactants: MnO_4^-, Fe^{2+} and H^+. The products are Mn^{2+}, Fe^{3+} and H_2O. Which two reactants change oxidation number? What does the third one do?

B3-P11 · Challenging · Given this half-reaction in basic solution: $OCl^- + H_2O + 2e^- \rightarrow Cl^- + 2OH^-$. Check the atoms and the charge. Find the oxidation number of chlorine before and after. Is it an oxidation or a reduction?

B3-P12 · Challenging · Given two half-reactions for hydrogen peroxide: $H_2O_2 \rightarrow O_2 + 2H^+ + 2e^-$ and $H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$. Join them and cancel what is on both sides. Explain why the net reaction is a disproportionation.