**MTA-ELTE Research Group on Inquiry-Based Chemistry Education**

**Research Programme for Public Education Development of the Hungarian Academy of Sciences**

**STUDENT SHEETS AND TEACHER’S NOTES OF THE SECOND SCHOOL YEAR (2022/2023.)**

It is important to note that the student sheets are not intended to be stand alone. They were used in class with an accompanying dialogue from the teacher. In other words, the teachers talked students through the sheets. Each following student sheet and teacher notes was part of a teacher guide file that contained detailed instructions for teachers how to prepare and guide the students through the activities. Those files are available in Hungarian at the following links:

Student sheet 7: **In the footsteps of the alchemists** [7. feladatlap: Az alkimisták nyomában](https://ttomc.elte.hu/rails/active_storage/blobs/eyJfcmFpbHMiOnsibWVzc2FnZSI6IkJBaHBBa2tPIiwiZXhwIjpudWxsLCJwdXIiOiJibG9iX2lkIn19--84293d915aedde80f9ea8665b56a7c6628b4d15c/7_Femek_2023_05_27_HONLAPRA.docx?disposition=attachment)

Student sheet 8: **Softening of hard water** [8. feladatlap: Kemény vizek lágyítása](https://ttomc.elte.hu/rails/active_storage/blobs/eyJfcmFpbHMiOnsibWVzc2FnZSI6IkJBaHBBa29PIiwiZXhwIjpudWxsLCJwdXIiOiJibG9iX2lkIn19--325b8547e7878d0ac6b65a8af34bc37b8169f04b/8_Vizlagyitas_2023_05_27_HONLAPRA.docx?disposition=attachment)

Student sheet 9: **Is the calcination of lime a combustion?[[1]](#footnote-1)** [9. feladatlap: Égés-e a mészégetés?](https://ttomc.elte.hu/rails/active_storage/blobs/eyJfcmFpbHMiOnsibWVzc2FnZSI6IkJBaHBBa3NPIiwiZXhwIjpudWxsLCJwdXIiOiJibG9iX2lkIn19--3fe5c76f4e7f8b136447563210705558ce8fea39/9_Meszegetes_NYOMTATNI_2023_05_27_HONLAPRA.docx?disposition=attachment)

Student sheet 10: **Does acid rain harm mussels and coral reefs?** [10. feladatlap: Bántja-e a savas eső a kagylókat és a korallzátonyokat?](https://ttomc.elte.hu/rails/active_storage/blobs/eyJfcmFpbHMiOnsibWVzc2FnZSI6IkJBaHBBa3dPIiwiZXhwIjpudWxsLCJwdXIiOiJibG9iX2lkIn19--d7eac124859cc1de6ea1c3e365fb875cf75da591/10_Savas_eso_kagylok_2023_05_27_HONLAPRA.docx?disposition=attachment)

Student sheet 11: **Can the topping of a “Dobos” cake[[2]](#footnote-2) be made from birch sugar?** [11. feladatlap: Készíthető-e a dobostorta teteje nyírfacukorból?](https://ttomc.elte.hu/rails/active_storage/blobs/eyJfcmFpbHMiOnsibWVzc2FnZSI6IkJBaHBBazBPIiwiZXhwIjpudWxsLCJwdXIiOiJibG9iX2lkIn19--8e39ec3067870bce71d55f9fa0fa740a0e18e57c/11_Cukrok_karamelliz%C3%A1l%C3%A1sa_2023_05_28_HONLAPRA.docx?disposition=attachment)

Student sheet 12: **From superhero to supervillain? - Creating mountains of waste from useful plastics** [12. feladatlap: Szuperhősből szupergonosz? – Hulladékhegyek keletkezése hasznos műanyagokból](https://ttomc.elte.hu/rails/active_storage/blobs/eyJfcmFpbHMiOnsibWVzc2FnZSI6IkJBaHBBazRPIiwiZXhwIjpudWxsLCJwdXIiOiJibG9iX2lkIn19--bcbac813a4d243c73a34fa70b51c3879c589148e/12_Muanyagok_2023_05_28_HONLAPRA.docx?disposition=attachment)

**Student sheet 7: In the footsteps of the alchemists**

(type 1: ‘step-by-step’ version for Group 1 students)

*"...we find a very informative part in the description of the mineral water around Banská Bystrica. As is well known, it was here, in the mines of the Herr Valley, that Ziementwasser was discovered (and also in the area around Szomolnok): the water containing blue vitriol, which was able to transform one substance - iron - into another - copper. All alchemists have used this phenomenon to search for a substance that could turn something else into gold*.[[3]](#footnote-3)" We now know that iron cannot be converted into copper because **chemical reactions cannot convert one chemical element into another**. So gold cannot be made in this way either. The iron atom **transfers electrons** to copper (II) ions dissolved in water, **reducing** them to elemental copper, while the iron atom itself is **oxidised** to iron (II) ions:

 **2e-  2e-**

 Fe + CuSO4 = FeSO4 + Cu The essence of the process: Fe + Cu2+ = Fe2+ + Cu

A similar process takes place when hydrogen gas is developed by reacting hydrochloric acid with zinc. The zinc atoms then transfer electrons to the hydrogen ions in the hydrochloric acid, reducing them to hydrogen atoms:

 **2e**- **2e-**

Zn + 2 HCl = ZnCl2 + H2 The essence of the process: Zn + 2 H+ = Zn2+ + H2

However, these reactions cannot take place the other way round. This is because metals and hydrogen can be arranged in a **reactivity series** according to their reducing power (i.e. electron transfer capacity). The following experiments will help us to determine where copper and aluminium are located in the series of **decreasing reducing power from left to right**, in the marked blanks.

K, Ca, Na, Mg, \_\_, Zn, Fe, Sn, **H**, \_\_, Hg, Ag, Au

MATERIALS AND EQUIPMENT: household hydrochloric acid (*w*=20%), piece of copper wire, piece of aluminium foil, 2 test tubes or other vessels, tweezers

|  |  |
| --- | --- |
| Experiment 1hydrochloric acid + piece of copper wire | Experiment 2hydrochloric acid + piece of aluminium foil |
| number of repetitions in class: | number of repetitions in class: |

THE STEPS OF THE EXPERIMENTS:

1. Pour about 3-3 cm3 of hydrochloric acid into the 2 test tubes/vessels.
2. Place a piece of copper wire in the first test tube/vessel with the tweezers.
3. In the second test tube/vessel, place the piece of aluminium foil with the tweezers.
4. Continuously observe the phenomena in the test tubes/vessels.
5. After 4-5 minutes, record the observations.

After the experiments are done, write down your observations and explanations. Complete the text of the CONCLUSION and LET'S THINK! sections by writing the correct words, underlining or framing the correct words, or ~~crossing out~~ the incorrect ones.

1. OBSERVATION:

Experiment 1: …………………………………………………………………………………………………………………………………………

Experiment 2: …………………………………………………………………………………………………………………………………………

2. Explanation:

Experiment 1: …………………………………………………………………………………………………………………………………………

Experiment 2: …………………………………………………………………………………………………………………………………………

3. CONCLUSION: The aluminium atom **can/cannot** reduce hydrogen ions (by electron transfer) to hydrogen atoms. **Aluminium** has a **lower/higher** reducing power than hydrogen. The copper atom **can/cannot** reduce hydrogen ions (by electron transfer) to hydrogen atoms. Copper has a **lower/higher** reducing power than hydrogen. Based on these results, add the chemical symbol of the metals under investigation to the reduction series.

K, Ca, Na, Mg, \_\_, Zn, Fe, Sn, **H**, \_\_, Hg, Ag

4. LET'S THINK!

In the introduction, we read that water containing copper (II) sulphate (i.e. "blue vitriol") forms a copper coating on iron objects. This is possible because the reducing power of iron is **higher/lower** than that of copper. Therefore, the iron atom transfers electrons to the copper (II) ions.

Despite its relatively high reducing power, aluminium is well resistant to environmental influences. This is because it has a solid, protective oxide layer on its surface. This is one of the reasons why aluminium is suitable for a wide range of applications. The protective layer of aluminium oxide dissolves in acid, but the process takes time. Balance the reaction equation:

… Al2O3 + …. HCl = … AlCl3 + … H2O

Due to aluminium oxide and aluminium dissolving in acids, holes in the aluminium foil are created when food containing acid (e.g. leftover lasagne) is covered with aluminium foil.

Unfortunately, the rust that forms on the surface of iron cannot protect it from the environmental impact, because it does not form a solid protective layer. Therefore, iron should be protected from rusting, for example by metal coatings. In the case of white tin, the iron sheet is protected by a tin (Sn) coating. In the case of galvanised iron, the iron sheet is covered with a zinc coating (Zn). ***In theory***, can these coatings be produced by immersing the iron sheet in a solution containing tin (II) ions or zinc ions?

Iron has a **lower/higher** reducing power than tin, so the iron atom **is able/unable** to transfer electrons to tin(II) ions, which **may/may not form** an elemental metal coating on the surface of the iron.

Iron has a **lower/higher** reducing power than zinc, so the iron atom **is able/unable** to transfer electrons to zinc ions, which **may/may not form** an elemental metal coating on the surface of the iron.

In the equations below, cross out the equals sign if the reaction does not take place. Mark the electron transfer in the equation of the reaction that does take place.

Fe + SnCl2 = FeCl2 + Sn Fe + ZnCl2 = FeCl2 + Zn

**Teacher notes for Student sheet 7: In the footsteps of the alchemists**

(type 1: ‘step-by-step’ version for Group 1 students)

Teachers are kindly asked to encourage their students to do experiments by highlighting the importance of experimentation in science and praising them when they think correctly.

*"...we find a very informative part in the description of the mineral water around Banská Bystrica. As is well known, it was here, in the mines of the Herr Valley, that Ziementwasser was discovered (and also in the area around Szomolnok): the water containing blue vitriol, which was able to transform one substance - iron - into another - copper. All alchemists have used this phenomenon to search for a substance that could turn something else into gold*.[[4]](#footnote-4)" We now know that iron cannot be converted into copper because **chemical reactions cannot convert one chemical element into another**. So gold cannot be made in this way either. The iron atom **transfers electrons** to copper (II) ions dissolved in water, **reducing** them to elemental copper, while the iron atom itself is **oxidised** to iron (II) ions:

 **2e-  2e-**

 Fe + CuSO4 = FeSO4 + Cu The essence of the process: Fe + Cu2+ = Fe2+ + Cu

A similar process takes place when hydrogen gas is developed by reacting hydrochloric acid with zinc. The zinc atoms then transfer electrons to the hydrogen ions in the hydrochloric acid, reducing them to hydrogen atoms:

 **2e**- **2e-**

Zn + 2 HCl = ZnCl2 + H2 The essence of the process: Zn + 2 H+ = Zn2+ + H2

However, these reactions cannot take place the other way round. This is because metals and hydrogen can be arranged in a **reactivity series** according to their reducing power (i.e. electron transfer capacity). The following experiments will help us to determine where copper and aluminium are located in the series of **decreasing reducing power from left to right**, in the marked blanks.

K, Ca, Na, Mg, \_\_, Zn, Fe, Sn, **H**, \_\_, Hg, Ag, Au

MATERIALS AND EQUIPMENT: household hydrochloric acid (*w*=20%), piece of copper wire, piece of aluminium foil, 2 test tubes or other vessels, tweezers

|  |  |
| --- | --- |
| Experiment 1hydrochloric acid + piece of copper wire | Experiment 2hydrochloric acid + piece of aluminium foil |
| number of repetitions in class: | number of repetitions in class: |

THE STEPS OF THE EXPERIMENTS:

1. Pour about 3-3 cm3 of hydrochloric acid into the 2 test tubes/vessels.
2. Place a piece of copper wire in the first test tube/vessel with the tweezers.
3. In the second test tube/vessel, place the piece of aluminium foil with the tweezers.
4. Continuously observe the phenomena in the test tubes/vessels.
5. After 4-5 minutes, record the observations.

After the experiments are done, write down your observations and explanations. Complete the text of the CONCLUSION and LET'S THINK! sections by writing the correct words, underlining or framing the correct words, or ~~crossing out~~ the incorrect ones.

1. OBSERVATION:

Experiment 1: With piece of copper wire, there is no change after a longer period of time.

Experiment 2: The piece of aluminium foil dissolves during increasingly violent, colourless, and odourless gas evolution, producing a colourless solution.

2. Explanation:

Experiment 1: Copper cannot transfer electrons to hydrogen ions (found in hydrochloric acid).

Experiment 2: Aluminium is able to transfer electrons to hydrogen ions, producing elementary hydrogen:

2 Al + 6 HCl = 2 AlCl3 + 3 H2

3. CONCLUSION: The aluminium atom **can/cannot** reduce hydrogen ions (by electron transfer) to hydrogen atoms. **Aluminium** has a **lower/higher**, reducing power than hydrogen. The copper atom **can/cannot**, reduce hydrogen ions (by electron transfer) to hydrogen atoms. Copper has a **lower/higher** reducing power than hydrogen. Based on these results, add the chemical symbol of the metals under investigation to the reduction series.

K, Ca, Na, Mg, Al, Zn, Fe, Sn, **H**, Cu, Hg, Ag

4. LET'S THINK!

In the introduction, we read that water containing copper (II) sulphate (i.e. "blue vitriol") forms a copper coating on iron objects. This is possible because the reducing power of iron is **higher**/**lower** than that of copper. Therefore, the iron atom transfers electrons to the copper (II) ions.

Despite its relatively high reducing power, aluminium is well resistant to environmental influences. This is because it has a solid, protective oxide layer on its surface. This is one of the reasons why aluminium is suitable for a wide range of applications. The protective layer of aluminium oxide dissolves in acid, but the process takes time. Balance the reaction equation:

Al2O3 + 6 HCl = 2 AlCl3 + 3 H2O

Due to aluminium oxide and aluminium dissolving in acids, holes in the aluminium foil are created when food containing acid (e.g. leftover lasagne) is covered with aluminium foil.

Unfortunately, the rust that forms on the surface of iron cannot protect it from the environmental impact, because it does not form a solid protective layer. Therefore, iron should be protected from rusting, for example by metal coatings. In the case of white tin, the iron sheet is protected by a tin (Sn) coating. In the case of galvanised iron, the iron sheet is covered with a zinc coating (Zn). ***In theory***, can these coatings be produced by immersing the iron sheet in a solution containing tin (II) ions or zinc ions?

Iron has a **lower/higher** reducing power than tin, so the iron atom **is able/unable** to transfer electrons to tin(II) ions, which **may/may not form** an elemental metal coating on the surface of the iron.

Iron has a **lower/higher** reducing power than zinc, so the iron atom **is able/unable** to transfer electrons to zinc ions, which **may/may not form** an elemental metal coating on the surface of the iron.

In the equations below, cross out the equals sign if the reaction does not take place. Mark the electron transfer in the equation of the reaction that does take place.

 2e-

Fe + SnCl2 = FeCl2 + Sn Fe + ZnCl2 ≠ FeCl2 + Zn

**Student sheet 7: In the footsteps of the alchemists**

(type 2: ‘step-by-step’ version + scheme of experimental design for Group 2 students)

*"...we find a very informative part in the description of the mineral water around Banská Bystrica. As is well known, it was here, in the mines of the Herr Valley, that Ziementwasser was discovered (and also in the area around Szomolnok): the water containing blue vitriol, which was able to transform one substance - iron - into another - copper. All alchemists have used this phenomenon to search for a substance that could turn something else into gold*.[[5]](#footnote-5)" We now know that iron cannot be converted into copper because **chemical reactions cannot convert one chemical element into another**. So gold cannot be made in this way either. The iron atom **transfers electrons** to copper (II) ions dissolved in water, **reducing** them to elemental copper, while the iron atom itself is **oxidised** to iron (II) ions:

 **2e-  2e-**

 Fe + CuSO4 = FeSO4 + Cu The essence of the process: Fe + Cu2+ = Fe2+ + Cu

A similar process takes place when hydrogen gas is developed by reacting hydrochloric acid with zinc. The zinc atoms then transfer electrons to the hydrogen ions in the hydrochloric acid, reducing them to hydrogen atoms:

 **2e**- **2e-**

Zn + 2 HCl = ZnCl2 + H2 The essence of the process: Zn + 2 H+ = Zn2+ + H2

However, these reactions cannot take place the other way round. This is because metals and hydrogen can be arranged in a **reactivity series** according to their reducing power (i.e. electron transfer capacity). The following experiments will help us to determine where copper and aluminium are located in the series of **decreasing reducing power from left to right**, in the marked blanks.

K, Ca, Na, Mg, \_\_, Zn, Fe, Sn, **H**, \_\_, Hg, Ag, Au

MATERIALS AND EQUIPMENT: household hydrochloric acid (*w*=20%), piece of copper wire, piece of aluminium foil, 2 test tubes or other vessels, tweezers

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| --- | --- |
| Experiment 1hydrochloric acid + piece of copper wire | Experiment 2hydrochloric acid + piece of aluminium foil |
| number of repetitions in class: | number of repetitions in class: |

THE STEPS OF THE EXPERIMENTS:

1. Pour about 3-3 cm3 of hydrochloric acid into the 2 test tubes/vessels.
2. Place a piece of copper wire in the first test tube/vessel with the tweezers.
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5. After 4-5 minutes, record the observations.

After the experiments are done, write down your observations and explanations. Complete the text of the CONCLUSION and LET'S THINK! sections by writing the correct words, underlining or framing the correct words, or ~~crossing out~~ the incorrect ones.

1. OBSERVATION:

Experiment 1: …………………………………………………………………………………………………………………………………………

Experiment 2: …………………………………………………………………………………………………………………………………………

2. Explanation:

Experiment 1: …………………………………………………………………………………………………………………………………………

Experiment 2: …………………………………………………………………………………………………………………………………………

3. CONCLUSION: The aluminium atom **can/cannot** reduce hydrogen ions (by electron transfer) to hydrogen atoms. **Aluminium** has a **lower/higher** reducing power than hydrogen. The copper atom **can/cannot** reduce hydrogen ions (by electron transfer) to hydrogen atoms. Copper has a **lower/higher** reducing power than hydrogen. Based on these results, add the chemical symbol of the metals under investigation to the reduction series.

K, Ca, Na, Mg, \_\_, Zn, Fe, Sn, **H**, \_\_, Hg, Ag

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

4. WHAT WAS THE INDEPENDENT VARIABLE THAT YOU HAD TO CHANGE IN THE EXPERIMENTS?

**YOU ARE ONLY ALLOWED TO CHANGE ONE FACTOR AT A TIME!**

……………………………………………………………………………………………………………………………………………………………………….……

5. WHAT WAS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDED ON THE INDEPENDENT VARIABLE?

……………………………………………………………………………………………………………………………………………………………………….……

6. HOW COULD YOU TEST THIS DEPENDENT VARIABLE?

……………………………………………………………………………………………………………………………………………………………………….……

7. THIS WAS THE ASSUMPTION (HYPOTHESIS):

If ………………………………………………………………………………………………………………………………………. (the independent

variable changes as intended), then ………………………………………………………………………………………. (the dependent variable will change in this way).

8. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a + sign!

Volume of hydrochloric acid

Volume of the glass

Concentration of hydrochloric acid

Temperature of hydrochloric acid

Mass of the metal particles

9. LET'S THINK!

In the introduction, we read that water containing copper (II) sulphate (i.e. "blue vitriol") forms a copper coating on iron objects. This is possible because the reducing power of iron is **higher/lower** than that of copper. Therefore, the iron atom transfers electrons to the copper (II) ions.

Despite its relatively high reducing power, aluminium is well resistant to environmental influences. This is because it has a solid, protective oxide layer on its surface. This is one of the reasons why aluminium is suitable for a wide range of applications. The protective layer of aluminium oxide dissolves in acid, but the process takes time. Balance the reaction equation:

… Al2O3 + …. HCl = … AlCl3 + … H2O

Due to aluminium oxide and aluminium dissolving in acids, holes in the aluminium foil are created when food containing acid (e.g. leftover lasagne) is covered with aluminium foil.

Unfortunately, the rust that forms on the surface of iron cannot protect it from the environmental impact, because it does not form a solid protective layer. Therefore, iron should be protected from rusting, for example by metal coatings. In the case of white tin, the iron sheet is protected by a tin (Sn) coating. In the case of galvanised iron, the iron sheet is covered with a zinc coating (Zn). ***In theory***, can these coatings be produced by immersing the iron sheet in a solution containing tin (II) ions or zinc ions?

Iron has a **lower/higher** reducing power than tin, so the iron atom **is able/unable** to transfer electrons to tin(II) ions, which **may/may not form** an elemental metal coating on the surface of the iron.

Iron has a **lower/higher** reducing power than zinc, so the iron atom **is able/unable** to transfer electrons to zinc ions, which **may/may not form** an elemental metal coating on the surface of the iron.

In the equations below, cross out the equals sign if the reaction does not take place. Mark the electron transfer in the equation of the reaction that does take place.

Fe + SnCl2 = FeCl2 + Sn Fe + ZnCl2 = FeCl2 + Zn

**Teacher notes for Student sheet 7: In the footsteps of the alchemists**

(type 2: ‘step-by-step’ version + scheme of experimental design for Group 2 students)

Teachers are kindly asked to encourage their students to answer questions about experiment design by highlighting its usefulness and praising them for thinking well.

*"...we find a very informative part in the description of the mineral water around Banská Bystrica. As is well known, it was here, in the mines of the Herr Valley, that Ziementwasser was discovered (and also in the area around Szomolnok): the water containing blue vitriol, which was able to transform one substance - iron - into another - copper. All alchemists have used this phenomenon to search for a substance that could turn something else into gold*.[[6]](#footnote-6)" We now know that iron cannot be converted into copper because **chemical reactions cannot convert one chemical element into another**. So gold cannot be made in this way either. The iron atom **transfers electrons** to copper (II) ions dissolved in water, **reducing** them to elemental copper, while the iron atom itself is **oxidised** to iron (II) ions:

 **2e-  2e-**

 Fe + CuSO4 = FeSO4 + Cu The essence of the process: Fe + Cu2+ = Fe2+ + Cu

A similar process takes place when hydrogen gas is developed by reacting hydrochloric acid with zinc. The zinc atoms then transfer electrons to the hydrogen ions in the hydrochloric acid, reducing them to hydrogen atoms:

 **2e**- **2e-**

Zn + 2 HCl = ZnCl2 + H2 The essence of the process: Zn + 2 H+ = Zn2+ + H2

However, these reactions cannot take place the other way round. This is because metals and hydrogen can be arranged in a **reactivity series** according to their reducing power (i.e. electron transfer capacity). The following experiments will help us to determine where copper and aluminium are located in the series of **decreasing reducing power from left to right**, in the marked blanks.

K, Ca, Na, Mg, \_\_, Zn, Fe, Sn, **H**, \_\_, Hg, Ag, Au

MATERIALS AND EQUIPMENT: household hydrochloric acid (*w*=20%), piece of copper wire, piece of aluminium foil, 2 test tubes or other vessels, tweezers

|  |  |
| --- | --- |
| Experiment 1hydrochloric acid + piece of copper wire | Experiment 2hydrochloric acid + piece of aluminium foil |
| number of repetitions in class: | number of repetitions in class: |

THE STEPS OF THE EXPERIMENTS:

1. Pour about 3-3 cm3 of hydrochloric acid into the 2 test tubes/vessels.
2. Place a piece of copper wire in the first test tube/vessel with the tweezers.
3. In the second test tube/vessel, place the piece of aluminium foil with the tweezers.
4. Continuously observe the phenomena in the test tubes/vessels.
5. After 4-5 minutes, record the observations.

After the experiments are done, write down your observations and explanations. Complete the text of the CONCLUSION and LET'S THINK! sections by writing the correct words, underlining or framing the correct words, or ~~crossing out~~ the incorrect ones.

1. OBSERVATION:

Experiment 1: With piece of copper wire, there is no change after a longer period of time.

Experiment 2: The piece of aluminium foil dissolves during increasingly violent colourless, and odourless gas evolution, producing a colourless solution.

2. Explanation:

Experiment 1: Copper cannot transfer electrons to hydrogen ions (found in hydrochloric acid).

Experiment 2: Aluminium is able to transfer electrons to hydrogen ions, producing elementary hydrogen:

2 Al + 6 HCl = 2 AlCl3 + 3 H2

3. CONCLUSION: The aluminium atom **can/cannot** reduce hydrogen ions (by electron transfer) to hydrogen atoms. **Aluminium** has a **lower/higher**, reducing power than hydrogen. The copper atom **can/cannot**, reduce hydrogen ions (by electron transfer) to hydrogen atoms. Copper has a **lower/higher** reducing power than hydrogen. Based on these results, add the chemical symbol of the metals under investigation to the reduction series.

K, Ca, Na, Mg, Al, Zn, Fe, Sn, **H**, Cu, Hg, Ag

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

4. WHAT WAS THE INDEPENDENT VARIABLE THAT YOU HAD TO CHANGE IN THE EXPERIMENTS?

**YOU ARE ONLY ALLOWED TO CHANGE ONE FACTOR AT A TIME!**

The material quality of metals. (The metal that was used.)

5. WHAT WAS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDED ON THE INDEPENDENT VARIABLE?

The occurrence of gas evolution.

6. HOW COULD YOU TEST THIS DEPENDENT VARIABLE?

By observing whether gas bubbles form for each metal when placed in hydrochloric acid.

7. THIS WAS THE ASSUMPTION (HYPOTHESIS):

If the metal atom is able to transfer electrons to the hydrogen ion (it has a higher reducing power) (the independent variable changes as intended), then colourless, and odourless gas evolution (hydrogen evolution) occurs (the dependent variable will change in this way).

8. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a + sign!

Volume of hydrochloric acid

Volume of the glass

**+** Concentration of hydrochloric acid

**+** Temperature of hydrochloric acid

Mass of the metal particles

9. LET'S THINK!

In the introduction, we read that water containing copper (II) sulphate (i.e. "blue vitriol") forms a copper coating on iron objects. This is possible because the reducing power of iron is **higher**/**lower** than that of copper. Therefore, the iron atom transfers electrons to the copper (II) ions.

Despite its relatively high reducing power, aluminium is well resistant to environmental influences. This is because it has a solid, protective oxide layer on its surface. This is one of the reasons why aluminium is suitable for a wide range of applications. The protective layer of aluminium oxide dissolves in acid, but the process takes time. Balance the reaction equation:

Al2O3 + 6 HCl = 2 AlCl3 + 3 H2O

Due to aluminium oxide and aluminium dissolving in acids, holes in the aluminium foil are created when food containing acid (e.g. leftover lasagne) is covered with aluminium foil.

Unfortunately, the rust that forms on the surface of iron cannot protect it from the environmental impact, because it does not form a solid protective layer. Therefore, iron should be protected from rusting, for example by metal coatings. In the case of white tin, the iron sheet is protected by a tin (Sn) coating. In the case of galvanised iron, the iron sheet is covered with a zinc coating (Zn). ***In theory***, can these coatings be produced by immersing the iron sheet in a solution containing tin (II) ions or zinc ions?

Iron has a **lower/higher** reducing power than tin, so the iron atom **is able/unable** to transfer electrons to tin(II) ions, which **may/may not form** an elemental metal coating on the surface of the iron.

Iron has a **lower/higher** reducing power than zinc, so the iron atom **is able/unable** to transfer electrons to zinc ions, which **may/may not form** an elemental metal coating on the surface of the iron.

In the equations below, cross out the equals sign if the reaction does not take place. Mark the electron transfer in the equation of the reaction that does take place.

 2e-

Fe + SnCl2 = FeCl2 + Sn Fe + ZnCl2 ≠ FeCl2 + Zn

**Student sheet 7: In the footsteps of the alchemists**

(type 3: experimental design following a scheme version for Group 3 students)

*"...we find a very informative part in the description of the mineral water around Banská Bystrica. As is well known, it was here, in the mines of the Herr Valley, that Ziementwasser was discovered (and also in the area around Szomolnok): the water containing blue vitriol, which was able to transform one substance - iron - into another - copper. All alchemists have used this phenomenon to search for a substance that could turn something else into gold*.[[7]](#footnote-7)" We now know that iron cannot be converted into copper because **chemical reactions cannot convert one chemical element into another**. So gold cannot be made in this way either. The iron atom **transfers electrons** to copper (II) ions dissolved in water, **reducing** them to elemental copper, while the iron atom itself is **oxidised** to iron (II) ions:

 **2e-  2e-**

 Fe + CuSO4 = FeSO4 + Cu The essence of the process: Fe + Cu2+ = Fe2+ + Cu

A similar process takes place when hydrogen gas is developed by reacting hydrochloric acid with zinc. The zinc atoms then transfer electrons to the hydrogen ions in the hydrochloric acid, reducing them to hydrogen atoms:

 **2e**- **2e-**

Zn + 2 HCl = ZnCl2 + H2 The essence of the process: Zn + 2 H+ = Zn2+ + H2

However, these reactions cannot take place the other way round. This is because metals and hydrogen can be arranged in a **reactivity series** according to their reducing power (i.e. electron transfer capacity). The following experiments will help us to determine where copper and aluminium are located in the series of **decreasing reducing power from left to right**, in the marked blanks.

K, Ca, Na, Mg, \_\_, Zn, Fe, Sn, **H**, \_\_, Hg, Ag, Au

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

MATERIALS AND EQUIPMENT: household hydrochloric acid (*w*=20%), piece of copper wire, piece of aluminium foil, 2 test tubes or other vessels, tweezers

1. WHAT IS THE INDEPENDENT VARIABLE THAT YOU HAVE TO CHANGE IN THE EXPERIMENTS?

**YOU ARE ONLY ALLOWED TO CHANGE ONE FACTOR AT A TIME!**

……………………………………………………………………………………………………………………………………………………………………….……

2. WHAT IS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDS ON THE INDEPENDENT VARIABLE?

……………………………………………………………………………………………………………………………………………………………………….……

3. HOW CAN YOU TEST THIS DEPENDENT VARIABLE?

……………………………………………………………………………………………………………………………………………………………………….……

4. THIS IS THE ASSUMPTION (HYPOTHESIS):

If ………………………………………………………………………………………………………………………………………. (the independent

variable changes as intended), then ………………………………………………………………………………………. (the dependent variable will change in this way).

5. HOW CAN THE INDEPENDENT VARIABLE CHANGE? Plan what to put in each test tubes/vessels!

|  |  |
| --- | --- |
| Experiment 1 | Experiment 2 |
| number of repetitions in class: | number of repetitions in class: |

6. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a + sign!

Volume of hydrochloric acid

Volume of the glass

Concentration of hydrochloric acid

Temperature of hydrochloric acid

Mass of the metal particles

7. THE STEPS OF THE EXPERIMENTS:

…………………………………………………………………………………………………………………………………………………………………………….

…………………………………………………………………………………………………………………………………………………………………………….

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After the experiments are done, write down your observations and explanations. Complete the text of the CONCLUSION and LET'S THINK! sections by writing the correct words, underlining or framing the correct words, or ~~crossing out~~ the incorrect ones.

8. OBSERVATION:

Experiment 1: …………………………………………………………………………………………………………………………………………

Experiment 2: …………………………………………………………………………………………………………………………………………

9. Explanation:

Experiment 1: …………………………………………………………………………………………………………………………………………

Experiment 2: …………………………………………………………………………………………………………………………………………

10. CONCLUSION: The aluminium atom **can/cannot** reduce hydrogen ions (by electron transfer) to hydrogen atoms. **Aluminium** has a **lower/higher** reducing power than hydrogen. The copper atom **can/cannot** reduce hydrogen ions (by electron transfer) to hydrogen atoms. Copper has a **lower/higher** reducing power than hydrogen. Based on these results, add the chemical symbol of the metals under investigation to the reduction series.

K, Ca, Na, Mg, \_\_, Zn, Fe, Sn, **H**, \_\_, Hg, Ag

11. LET'S THINK!

In the introduction, we read that water containing copper (II) sulphate (i.e. "blue vitriol") forms a copper coating on iron objects. This is possible because the reducing power of iron is **higher/lower** than that of copper. Therefore, the iron atom transfers electrons to the copper (II) ions.

Despite its relatively high reducing power, aluminium is well resistant to environmental influences. This is because it has a solid, protective oxide layer on its surface. This is one of the reasons why aluminium is suitable for a wide range of applications. The protective layer of aluminium oxide dissolves in acid, but the process takes time. Balance the reaction equation:

… Al2O3 + …. HCl = … AlCl3 + … H2O

Due to aluminium oxide and aluminium dissolving in acids, holes in the aluminium foil are created when food containing acid (e.g. leftover lasagne) is covered with aluminium foil.

Unfortunately, the rust that forms on the surface of iron cannot protect it from the environmental impact, because it does not form a solid protective layer. Therefore, iron should be protected from rusting, for example by metal coatings. In the case of white tin, the iron sheet is protected by a tin (Sn) coating. In the case of galvanised iron, the iron sheet is covered with a zinc coating (Zn). ***In theory***, can these coatings be produced by immersing the iron sheet in a solution containing tin (II) ions or zinc ions?

Iron has a **lower/higher** reducing power than tin, so the iron atom **is able/unable** to transfer electrons to tin(II) ions, which **may/may not form** an elemental metal coating on the surface of the iron.

Iron has a **lower/higher** reducing power than zinc, so the iron atom **is able/unable** to transfer electrons to zinc ions, which **may/may not form** an elemental metal coating on the surface of the iron.

In the equations below, cross out the equals sign if the reaction does not take place. Mark the electron transfer in the equation of the reaction that does take place.

Fe + SnCl2 = FeCl2 + Sn Fe + ZnCl2 = FeCl2 + Zn

**Teacher notes for Student sheet 7: In the footsteps of the alchemists**

(type 3: experimental design following a scheme version for Group 3 students)

Teachers are kindly asked to encourage their students to answer questions about experiment design by highlighting its usefulness and praising them for thinking well.

*"...we find a very informative part in the description of the mineral water around Banská Bystrica. As is well known, it was here, in the mines of the Herr Valley, that Ziementwasser was discovered (and also in the area around Szomolnok): the water containing blue vitriol, which was able to transform one substance - iron - into another - copper. All alchemists have used this phenomenon to search for a substance that could turn something else into gold*.[[8]](#footnote-8)" We now know that iron cannot be converted into copper because **chemical reactions cannot convert one chemical element into another**. So gold cannot be made in this way either. The iron atom **transfers electrons** to copper (II) ions dissolved in water, **reducing** them to elemental copper, while the iron atom itself is **oxidised** to iron (II) ions:

 **2e-  2e-**

 Fe + CuSO4 = FeSO4 + Cu The essence of the process: Fe + Cu2+ = Fe2+ + Cu

A similar process takes place when hydrogen gas is developed by reacting hydrochloric acid with zinc. The zinc atoms then transfer electrons to the hydrogen ions in the hydrochloric acid, reducing them to hydrogen atoms:

 **2e**- **2e-**

Zn + 2 HCl = ZnCl2 + H2 The essence of the process: Zn + 2 H+ = Zn2+ + H2

However, these reactions cannot take place the other way round. This is because metals and hydrogen can be arranged in a **reactivity series** according to their reducing power (i.e. electron transfer capacity). The following experiments will help us to determine where copper and aluminium are located in the series of **decreasing reducing power from left to right**, in the marked blanks.

K, Ca, Na, Mg, \_\_, Zn, Fe, Sn, **H**, \_\_, Hg, Ag, Au

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

MATERIALS AND EQUIPMENT: household hydrochloric acid (*w*=20%), piece of copper wire, piece of aluminium foil, 2 test tubes or other vessels, tweezers

1. WHAT IS THE INDEPENDENT VARIABLE THAT YOU HAVE TO CHANGE IN THE EXPERIMENTS?

**YOU ARE ONLY ALLOWED TO CHANGE ONE FACTOR AT A TIME!**

The material quality of metals. (The metal that was used.)

2. WHAT IS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDS ON THE INDEPENDENT VARIABLE?

The occurrence of gas evolution.

3. HOW CAN YOU TEST THIS DEPENDENT VARIABLE?

By observing whether gas bubbles form for each metal when placed in hydrochloric acid.

4. THIS IS THE ASSUMPTION (HYPOTHESIS):

If the metal atom is able to transfer electrons to the hydrogen ion (it has a higher reducing power) (the independent variable changes as intended), then colourless, and odourless gas evolution (hydrogen evolution) occurs (the dependent variable will change in this way).

5. HOW CAN THE INDEPENDENT VARIABLE CHANGE? Plan what to put in each test tubes/vessels!

|  |  |
| --- | --- |
| Experiment 1hydrochloric acid + piece of copper wire | Experiment 2hydrochloric acid + piece of aluminium foil |
| number of repetitions in class: | number of repetitions in class: |

6. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a + sign!

Volume of hydrochloric acid

Volume of the glass

**+** Concentration of hydrochloric acid

**+** Temperature of hydrochloric acid

Mass of the metal particles

7. THE STEPS OF THE EXPERIMENTS:

1. Pour about 3-3 cm3 of hydrochloric acid into the 2 test tubes/vessels.
2. Place a piece of copper wire in the first test tube/vessel with the tweezers.
3. In the second test tube/vessel, place the piece of aluminium foil with the tweezers.
4. Continuously observe the phenomena in the test tubes/vessels.
5. After 4-5 minutes, record the observations.

After the experiments are done, write down your observations and explanations. Complete the text of the CONCLUSION and LET'S THINK! sections by writing the correct words, underlining or framing the correct words, or ~~crossing out~~ the incorrect ones.

8. OBSERVATION:

Experiment 1: With piece of copper wire, there is no change after a longer period of time.

Experiment 2: The piece of aluminium foil dissolves during increasingly violent colourless, and odourless gas evolution, producing a colourless solution.

9. Explanation:

Experiment 1: Copper cannot transfer electrons to hydrogen ions (found in hydrochloric acid).

Experiment 2: Aluminium is able to transfer electrons to hydrogen ions, producing elementary hydrogen:

2 Al + 6 HCl = 2 AlCl3 + 3 H2

10. CONCLUSION: The aluminium atom **can/cannot** reduce hydrogen ions (by electron transfer) to hydrogen atoms. **Aluminium** has a **lower/higher**, reducing power than hydrogen. The copper atom **can/cannot**, reduce hydrogen ions (by electron transfer) to hydrogen atoms. Copper has a **lower/higher** reducing power than hydrogen. Based on these results, add the chemical symbol of the metals under investigation to the reduction series.

K, Ca, Na, Mg, Al, Zn, Fe, Sn, **H**, Cu, Hg, Ag

11. LET'S THINK!

In the introduction, we read that water containing copper (II) sulphate (i.e. "blue vitriol") forms a copper coating on iron objects. This is possible because the reducing power of iron is **higher**/**lower** than that of copper. Therefore, the iron atom transfers electrons to the copper (II) ions.

Despite its relatively high reducing power, aluminium is well resistant to environmental influences. This is because it has a solid, protective oxide layer on its surface. This is one of the reasons why aluminium is suitable for a wide range of applications. The protective layer of aluminium oxide dissolves in acid, but the process takes time. Balance the reaction equation:

Al2O3 + 6 HCl = 2 AlCl3 + 3 H2O

Due to aluminium oxide and aluminium dissolving in acids, holes in the aluminium foil are created when food containing acid (e.g. leftover lasagne) is covered with aluminium foil.

Unfortunately, the rust that forms on the surface of iron cannot protect it from the environmental impact, because it does not form a solid protective layer. Therefore, iron should be protected from rusting, for example by metal coatings. In the case of white tin, the iron sheet is protected by a tin (Sn) coating. In the case of galvanised iron, the iron sheet is covered with a zinc coating (Zn). ***In theory***, can these coatings be produced by immersing the iron sheet in a solution containing tin (II) ions or zinc ions?

Iron has a **lower/higher** reducing power than tin, so the iron atom **is able/unable** to transfer electrons to tin(II) ions, which **may/may not form** an elemental metal coating on the surface of the iron.

Iron has a **lower/higher** reducing power than zinc, so the iron atom **is able/unable** to transfer electrons to zinc ions, which **may/may not form** an elemental metal coating on the surface of the iron.

In the equations below, cross out the equals sign if the reaction does not take place. Mark the electron transfer in the equation of the reaction that does take place.

 2e-

Fe + SnCl2 = FeCl2 + Sn Fe + ZnCl2 ≠ FeCl2 + Zn

END OF THE 7th STUDENT SHEETS AND TEACHER NOTES

**Student sheet 8: Softening of hard water**

(type 1: ‘step-by-step’ version for Group 1 students)

**Limescale**, a substance that precipitates from **hard water**, forms an insulating coating on the heating elements of washing machines, coffee machines, boilers and kettles. This **increases the energy demand** for heating. Calcium compounds and magnesium compounds, which cause the hardness of water, precipitate with soap and similar detergents. They thus inhibit the **formation of foam** and reduce the **washing effect**. Using **too much soap, detergent, and acidic chemicals to dissolve limescale damages the environment and costs a lot of money**. This is why **water softening** is needed, which we will now look at. How does soap behave in distilled water, which models a soft water, and in mineral water, which models a hard water with a high calcium ion and magnesium ion content? Check out the teacher's experiment!

Water softeners are **water-soluble**, but they form a **poorly water-soluble compound (precipitate)** with calcium and magnesium ions, which cause water hardness. In the following experiments, you will investigate whether **tribasic** (trisodium-phosphate, Na3PO4) and **washing soda** (Na2CO3), which are recommended for water softening, really have a water softening effect.

MATERIALS AND EQUIPMENT: mineral water, tribasic (trisodium phosphate), washing soda, soap solution, test tube rack, 3 test tubes, 3 rubber stoppers, 2 beakers, measuring cylinder, 2 lab spoons, Pasteur pipette, ruler.

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):mineral water + soap solution | Experiment 2: mineral water + tribasic (trisodium phosphate) + soap solution | Experiment 3: mineral water + washing soda + soap solution |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Measure 5-5 cm3 of mineral water into each of the three numbered tubes.

(2) In the second test tube, a small lab spoonful of tribasic (trisodium phosphate) is sprinkled and dissolved by shaking.

(3) In the third tube, add a small lab spoonful of washing soda and dissolve by shaking.

(4) Add 1-1 cm3 of soap solution to each of the three test tubes.

(5) Plug the test tubes and shake each tube vigorously up and down ten times.

(6) Using a ruler, measure the height of the resulting soap foam.

After the experiments are done, write down your observations. Complete the text by writing the correct words, underlining or framing the correct words or ~~crossing out~~ the incorrect ones.

1. OBSERVATION: …………………………………………………………………………………………………………………………………………………

…………………………………………………………………………………………………………………………………………………………………………….

2. Explanation: …………………………………………………………………………………………………………………………………………………

3. Write down the equations for water softening with tribasic (trisodium phosphate) and washing soda for hard water containing calcium chloride and magnesium chloride.

……………………………………………………………………………………………………………………………………………………………….

……………………………………………………………………………………………………………………………………………………………….

4. CONCLUSION:

Washing soda (Na2CO3) is **suitable/not suitable** for water softening.

Tribasic (trisodium, Na3PO4) is **suitable/not suitable** for water softening.

Unfortunately, **phosphates** cause algae growth in natural water, so we try to avoid their use. It is therefore better to use **phosphate-free washing powders**. These either contain non-soap-like particles with dual solubility or bind the calcium and magnesium ions with mineral substances (e.g. zeolites).

5. LET’S THINK! According to several websites, the commonly used household baking soda (chemical name: sodium bicarbonate, formula: NaHCO3) is also suitable for water softening. Can it really be used to soften water? Check out the teacher's experiment!

The compounds of calcium and magnesium ions with the bicarbonate ion are **water soluble/precipitates**.

Baking soda (**NaHCO3**) is **suitable/not suitable** for water softening.

The formation of stalactites in limestone caves and the formation of limescale in the homes is chemically similar process, but they take place at different rates. Limestone, stalactites and limescale are all composed mainly of calcium carbonate. What is the chemical process by which stalactites and limescale are formed? Complete the diagram with the missing reaction equations. Circle the vertical arrows pointing upwards if the amount below needs to be increased, or the arrows pointing downwards if it needs to be decreased for the process to take place.

Carbon dioxide dissolves in water and reacts with calcium carbonate in limestone. This converts it to water-soluble calcium bicarbonate, forming hard water.

…………… + …………… + …………… = ……………

Hard water containing calcium bicarbonate loses its carbon dioxide content and precipitates as calcium carbonate-contained by limescale or stalactites.

…………… = …………… + …………… + ……………

temperature

temperature

↑↓

↑↓

**Teacher notes for Student sheet 8: Softening of hard water**

(type 1: ‘step-by-step’ version for Group 1 students)

Teachers are kindly asked to encourage their students to do experiments by highlighting the importance of experimentation in science and praising them when they think correctly.

**Limescale**, a substance that precipitates from **hard water**, forms an insulating coating on the heating elements of washing machines, coffee machines, boilers and kettles. This **increases the energy demand** for heating. Calcium compounds and magnesium compounds, which cause the hardness of water, precipitate with soap and similar detergents. They thus inhibit the **formation of foam** and reduce the **washing effect**. Using **too much soap, detergent, and acidic chemicals to dissolve limescale damages the environment and costs a lot of money**. This is why **water softening** is needed, which we will now look at. How does soap behave in distilled water, which models a soft water, and in mineral water, which models a hard water with a high calcium ion and magnesium ion content? Check out the teacher's experiment!

Water softeners are **water-soluble**, but they form a **poorly water-soluble compound (precipitate)** with calcium and magnesium ions, which cause water hardness. In the following experiments, you will investigate whether **tribasic** (trisodium-phosphate, Na3PO4) and **washing soda** (Na2CO3), which are recommended for water softening, really have a water softening effect.

MATERIALS AND EQUIPMENT: mineral water, tribasic (trisodium phosphate), washing soda, soap solution, test tube rack, 3 test tubes, 3 rubber stoppers, 2 beakers, measuring cylinder, 2 lab spoons, Pasteur pipette, ruler.

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):mineral water + soap solution | Experiment 2: mineral water + tribasic (trisodium phosphate) + soap solution | Experiment 3: mineral water + washing soda + soap solution |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Measure 5-5 cm3 of mineral water into each of the three numbered tubes.

(2) In the second test tube, a small lab spoonful of tribasic (trisodium phosphate) is sprinkled and dissolved by shaking.

(3) In the third tube, add a small lab spoonful of washing soda and dissolve by shaking.

(4) Add 1-1 cm3 of soap solution to each of the three test tubes.

(5) Plug the test tubes and shake each tube vigorously up and down ten times.

(6) Using a ruler, measure the height of the resulting soap foam.

After the experiments are done, write down your observations. Complete the text by writing the correct words, underlining or framing the correct words or ~~crossing out~~ the incorrect ones.

1. OBSERVATION: The tribasic (trisodium) and washing soda turned the mineral water opalescent. In test tube 1 the foam is about 0 − 1 cm high, in test tube 2 about 5 cm high and in test tube 3 about 3 cm high.

2. Explanation: Phosphate and carbonate ions form a precipitate with calcium and magnesium ions.

3. Write down the equations for water softening with tribasic (trisodium phosphate) and washing soda for hard water containing calcium chloride and magnesium chloride.

CaCl2 + Na2CO3 = CaCO3 + 2 NaClMgCl2 + Na2CO3 = MgCO3 + 2 NaCl

3 CaCl2 + 2 Na3PO4 = Ca3(PO4)2 + 6 NaCl3 MgCl2 + 2 Na3PO4 = Mg3(PO4)2 + 6 NaCl

4. CONCLUSION:

Washing soda (Na2CO3) is **suitable/not suitable** for water softening.

Tribasic (trisodium, Na3PO4) is **suitable/not suitable** for water softening.

Unfortunately, **phosphates** cause algae growth in natural water, so we try to avoid their use. It is therefore better to use **phosphate-free washing powders**. These either contain non-soap-like particles with dual solubility or bind the calcium and magnesium ions with mineral substances (e.g. zeolites).

5. LET’S THINK! According to several websites, the commonly used household baking soda (chemical name: sodium bicarbonate, formula: NaHCO3) is also suitable for water softening. Can it really be used to soften water? Check out the teacher's experiment!

The compounds of calcium and magnesium ions with the bicarbonate ion are **water soluble/precipitates**.

Baking soda (**NaHCO3**) is **suitable/not suitable** for water softening.

The formation of stalactites in limestone caves and the formation of limescale in the homes is chemically similar process, but they take place at different rates. Limestone, stalactites and limescale are all composed mainly of calcium carbonate. What is the chemical process by which stalactites and limescale are formed? Complete the diagram with the missing reaction equations. Circle the vertical arrows pointing upwards if the amount below needs to be increased, or the arrows pointing downwards if it needs to be decreased for the process to take place.

Carbon dioxide dissolves in water and reacts with calcium carbonate in limestone. This converts it to water-soluble calcium bicarbonate, forming hard water.
CaCO3 + H2O + CO2 = Ca(HCO3)2

Hard water containing calcium bicarbonate loses its carbon dioxide content and precipitates as calcium carbonate-contained by limescale or stalactites.
Ca(HCO3)2 = CaCO3 + H2O + CO2

temperature

temperature

↑↓

↑↓

**Student sheet 8: Softening of hard water**

(type 2: ‘step-by-step’ version + scheme of experimental design for Group 2 students)

**Limescale**, a substance that precipitates from **hard water**, forms an insulating coating on the heating elements of washing machines, coffee machines, boilers and kettles. This **increases the energy demand** for heating. Calcium compounds and magnesium compounds, which cause the hardness of water, precipitate with soap and similar detergents. They thus inhibit the **formation of foam** and reduce the **washing effect**. Using **too much soap, detergent, and acidic chemicals to dissolve limescale damages the environment and costs a lot of money**. This is why **water softening** is needed, which we will now look at. How does soap behave in distilled water, which models a soft water, and in mineral water, which models a hard water with a high calcium ion and magnesium ion content? Check out the teacher's experiment!

Water softeners are **water-soluble**, but they form a **poorly water-soluble compound (precipitate)** with calcium and magnesium ions, which cause water hardness. In the following experiments, you will investigate whether **tribasic** (trisodium-phosphate, Na3PO4) and **washing soda** (Na2CO3), which are recommended for water softening, really have a water softening effect.

MATERIALS AND EQUIPMENT: mineral water, tribasic (trisodium phosphate), washing soda, soap solution, test tube rack, 3 test tubes, 3 rubber stoppers, 2 beakers, measuring cylinder, 2 lab spoons, Pasteur pipette, ruler.

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):mineral water + soap solution | Experiment 2: mineral water + tribasic (trisodium phosphate) + soap solution | Experiment 3: mineral water + washing soda + soap solution |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Measure 5-5 cm3 of mineral water into each of the three numbered tubes.

(2) In the second test tube, a small lab spoonful of tribasic (trisodium phosphate) is sprinkled and dissolved by shaking.

(3) In the third tube, add a small lab spoonful of washing soda and dissolve by shaking.

(4) Add 1-1 cm3 of soap solution to each of the three test tubes.

(5) Plug the test tubes and shake each tube vigorously up and down ten times.

(6) Using a ruler, measure the height of the resulting soap foam.

After the experiments are done, write down your observations. Complete the text by writing the correct words, underlining or framing the correct words or ~~crossing out~~ the incorrect ones.

1. OBSERVATION: ……………………………………………………………………………………………………………………………………………………

…………………………………………………………………………………………………………………………………………………………………………….

2. Explanation: …………………………………………………………………………………………………………………………………………………

3. Write down the equations for water softening with tribasic (trisodium phosphate) and washing soda for hard water containing calcium chloride and magnesium chloride.

……………………………………………………………………………………………………………………………………………………………….

……………………………………………………………………………………………………………………………………………………………….

4. CONCLUSION:

Washing soda (Na2CO3) is **suitable/not suitable** for water softening.

Ttribasic (trisodium, Na3PO4) is **suitable/not suitable** for water softening.

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

The following table shows the solubility data of salts that can be derived from the ions given. In it, the answer to the question "Soluble?" is "**Good**", meaning that the compound of cation and anion **has good water solubility**, and "**No**", meaning that the precipitate is poorly soluble or **not soluble** at all.

|  |  |
| --- | --- |
| **Cations** | **Anions** |
| OH− | Cl− | S2− | $$SO\_{4}^{2-}$$ | $$PO\_{4}^{3-}$$ | $$CO\_{3}^{2-}$$ | $$NO\_{3}^{-}$$ |
| Na+ | Good | Good | Good | Good | Good | Good | Good |
| K+ | Good | Good | Good | Good | Good | Good | Good |
| Mg2+ | No | Good | Good | Good | No | No | Good |
| Ca2+ | Slightly | Good | Slightly | Slightly | No | No | Good |
| Ba2+ | Good | Good | Good | No | No | No | Good |
| Al3+ | No | Good | − | Good | No | − | Good |
| Zn2+ | No | Good | No | Good | No | No | Good |
| Ag+ | − | No | No | Slightly | No | No | Good |
| Cu2+ | No | Good | No | Good | No | No | Good |
| Pb2+ | No | Slightly | No | No | No | No | Good |
| Fe2+ | No | Good | No | Good | No | No | Good |
| Fe3+ | No | Good | − | Good | No | No | Good |

We can use the table to find anions that precipitate with both **Ca2+** and **Mg2+**. These are the phosphate ion ($PO\_{4}^{3-}$) and the carbonate ion ($CO\_{3}^{2-}$). Both anions form a water-soluble compound with **Na+** and **K+**, and therefore Na2CO3, Na3PO4, K2CO3 and K3PO4 are suitable for water softening. Of the four compounds, tribasic (trisodium, Na3PO4) and washing soda (Na2CO3) are the more economical (cheaper) solutions.

5. WHAT WAS THE INDEPENDENT VARIABLE THAT YOU HAD TO CHANGE IN THE EXPERIMENTS?

**YOU ARE ONLY ALLOWED TO CHANGE ONE FACTOR AT A TIME!**

……………………………………………………………………………………………………………………………………………………………………….……

6. WHAT WAS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDED ON THE INDEPENDENT VARIABLE?

……………………………………………………………………………………………………………………………………………………………………….……

7. HOW COULD YOU TEST THIS DEPENDENT VARIABLE?

……………………………………………………………………………………………………………………………………………………………………….……

8. THIS WAS THE ASSUMPTION (HYPOTHESIS):

If ………………………………………………………………………………………………………………………………………. (the independent

variable changes as intended), then ………………………………………………………………………………………. (the dependent variable will change in this way).

9. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a **x** sign!

[ ]  The volume of the water samples. [ ]  The diameter of the test tubes. [ ]  The concentration of the soap solution.

[ ]  The volume of the soap solution. [ ]  The degree of shaking. [ ]  The ruler used for the measurement.

Unfortunately, **phosphates** cause algae growth in natural water, so we try to avoid their use. It is therefore better to use **phosphate-free washing powders**. These either contain non-soap-like particles with dual solubility or bind the calcium and magnesium ions with mineral substances (e.g. zeolites).

10. LET’S THINK! According to several websites, the commonly used household baking soda (chemical name: sodium bicarbonate, formula: NaHCO3) is also suitable for water softening. Can it really be used to soften water? Check out the teacher's experiment!

The compounds of calcium and magnesium ions with the bicarbonate ion are **water soluble/precipitates**.

Baking soda (**NaHCO3**) is **suitable/not suitable** for water softening.

The formation of stalactites in limestone caves and the formation of limescale in the homes is chemically similar process, but they take place at different rates. Limestone, stalactites and limescale are all composed mainly of calcium carbonate. What is the chemical process by which stalactites and limescale are formed? Complete the diagram with the missing reaction equations. Circle the vertical arrows pointing upwards if the amount below needs to be increased, or the arrows pointing downwards if it needs to be decreased for the process to take place.

Carbon dioxide dissolves in water and reacts with calcium carbonate in limestone. This converts it to water-soluble calcium bicarbonate, forming hard water.

…………… + …………… + …………… = ……………

Hard water containing calcium bicarbonate loses its carbon dioxide content and precipitates as calcium carbonate-contained by limescale or stalactites.

…………… = …………… + …………… + ……………

temperature

temperature

↑↓

↑↓

**Teacher notes for Student sheet 8: Softening of hard water**

(type 2: ‘step-by-step’ version + scheme of experimental design for Group 2 students)

Teachers are kindly asked to encourage their students to answer questions about experiment design by highlighting its usefulness and praising them for thinking well.

**Limescale**, a substance that precipitates from **hard water**, forms an insulating coating on the heating elements of washing machines, coffee machines, boilers and kettles. This **increases the energy demand** for heating. Calcium compounds and magnesium compounds, which cause the hardness of water, precipitate with soap and similar detergents. They thus inhibit the **formation of foam** and reduce the **washing effect**. Using **too much soap, detergent, and acidic chemicals to dissolve limescale damages the environment and costs a lot of money**. This is why **water softening** is needed, which we will now look at. How does soap behave in distilled water, which models a soft water, and in mineral water, which models a hard water with a high calcium ion and magnesium ion content? Check out the teacher's experiment!

Water softeners are **water-soluble**, but they form a **poorly water-soluble compound (precipitate)** with calcium and magnesium ions, which cause water hardness. In the following experiments, you will investigate whether **tribasic** (trisodium-phosphate, Na3PO4) and **washing soda** (Na2CO3), which are recommended for water softening, really have a water softening effect.

MATERIALS AND EQUIPMENT: mineral water, tribasic (trisodium phosphate), washing soda, soap solution, test tube rack, 3 test tubes, 3 rubber stoppers, 2 beakers, measuring cylinder, 2 lab spoons, Pasteur pipette, ruler.

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):mineral water + soap solution | Experiment 2: mineral water + tribasic (trisodium phosphate) + soap solution | Experiment 3: mineral water + washing soda + soap solution |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Measure 5-5 cm3 of mineral water into each of the three numbered tubes.

(2) In the second test tube, a small lab spoonful of tribasic (trisodium phosphate) is sprinkled and dissolved by shaking.

(3) In the third tube, add a small lab spoonful of washing soda and dissolve by shaking.

(4) Add 1-1 cm3 of soap solution to each of the three test tubes.

(5) Plug the test tubes and shake each tube vigorously up and down ten times.

(6) Using a ruler, measure the height of the resulting soap foam.

After the experiments are done, write down your observations. Complete the text by writing the correct words, underlining or framing the correct words or ~~crossing out~~ the incorrect ones.

1. OBSERVATION: The tribasic (trisodium) and washing soda turned the mineral water opalescent. In test tube 1 the foam is about 0 − 1 cm high, in test tube 2 about 5 cm high and in test tube 3 about 3 cm high.

2. Explanation: Phosphate and carbonate ions form a precipitate with calcium and magnesium ions.

3. Write down the equations for water softening with tribasic (trisodium phosphate) and washing soda for hard water containing calcium chloride and magnesium chloride.

CaCl2 + Na2CO3 = CaCO3 + 2 NaClMgCl2 + Na2CO3 = MgCO3 + 2 NaCl

3 CaCl2 + 2 Na3PO4 = Ca3(PO4)2 + 6 NaCl3 MgCl2 + 2 Na3PO4 = Mg3(PO4)2 + 6 NaCl

4. CONCLUSION:

Washing soda (Na2CO3) is **suitable/not suitable** for water softening.

Tribasic (trisodium, Na3PO4) is **suitable/not suitable** for water softening.

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

The following table shows the solubility data of salts that can be derived from the ions given. In it, the answer to the question "Soluble?" is "**Good**", meaning that the compound of cation and anion **has good water solubility**, and "**No**", meaning that the precipitate is poorly soluble or **not soluble** at all.

|  |  |
| --- | --- |
| **Cations** | **Anions** |
| OH− | Cl− | S2− | $$SO\_{4}^{2-}$$ | $$PO\_{4}^{3-}$$ | $$CO\_{3}^{2-}$$ | $$NO\_{3}^{-}$$ |
| Na+ | Good | Good | Good | Good | Good | Good | Good |
| K+ | Good | Good | Good | Good | Good | Good | Good |
| Mg2+ | No | Good | Good | Good | No | No | Good |
| Ca2+ | Slightly | Good | Slightly | Slightly | No | No | Good |
| Ba2+ | Good | Good | Good | No | No | No | Good |
| Al3+ | No | Good | − | Good | No | − | Good |
| Zn2+ | No | Good | No | Good | No | No | Good |
| Ag+ | − | No | No | Slightly | No | No | Good |
| Cu2+ | No | Good | No | Good | No | No | Good |
| Pb2+ | No | Slightly | No | No | No | No | Good |
| Fe2+ | No | Good | No | Good | No | No | Good |
| Fe3+ | No | Good | − | Good | No | No | Good |

We can use the table to find anions that precipitate with both **Ca2+** and **Mg2+**. These are the phosphate ion ($PO\_{4}^{3-}$) and the carbonate ion ($CO\_{3}^{2-}$). Both anions form a water-soluble compound with **Na+** and **K+**, and therefore Na2CO3, Na3PO4, K2CO3 and K3PO4 are suitable for water softening. Of the four compounds, tribasic (trisodium, Na3PO4) and washing soda (Na2CO3) are the more economical (cheaper) solutions.

5. WHAT WAS THE INDEPENDENT VARIABLE THAT YOU HAD TO CHANGE IN THE EXPERIMENTS?

**YOU ARE ONLY ALLOWED TO CHANGE ONE FACTOR AT A TIME!**

The substance added to the mineral water in addition to the soap solution.

6. WHAT WAS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDED ON THE INDEPENDENT VARIABLE?

Hardness of the water sample.

7. HOW COULD YOU TEST THIS DEPENDENT VARIABLE?

By measuring the height of the soap foam.

8. THIS WAS THE ASSUMPTION (HYPOTHESIS):

If trisodium or washing soda is added to the water sample (the independent variable changes as intended), then the hardness of the water is reduced (the dependent variable will change in this way).

9. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a **x** sign!

[x]  The volume of the water samples. [x]  The diameter of the test tubes. [x]  The concentration of the soap solution.

[x]  The volume of the soap solution. [x]  The degree of shaking. [ ]  The ruler used for the measurement.

Unfortunately, **phosphates** cause algae growth in natural water, so we try to avoid their use. It is therefore better to use **phosphate-free washing powders**. These either contain non-soap-like particles with dual solubility or bind the calcium and magnesium ions with mineral substances (e.g. zeolites).

10. LET’S THINK! According to several websites, the commonly used household baking soda (chemical name: sodium bicarbonate, formula: NaHCO3) is also suitable for water softening. Can it really be used to soften water? Check out the teacher's experiment!

The compounds of calcium and magnesium ions with the bicarbonate ion are **water soluble/precipitates**.

Baking soda (**NaHCO3**) is **suitable/not suitable** for water softening.

The formation of stalactites in limestone caves and the formation of limescale in the homes is chemically similar process, but they take place at different rates. Limestone, stalactites and limescale are all composed mainly of calcium carbonate. What is the chemical process by which stalactites and limescale are formed? Complete the diagram with the missing reaction equations. Circle the vertical arrows pointing upwards if the amount below needs to be increased, or the arrows pointing downwards if it needs to be decreased for the process to take place.

Carbon dioxide dissolves in water and reacts with calcium carbonate in limestone. This converts it to water-soluble calcium bicarbonate, forming hard water.
CaCO3 + H2O + CO2 = Ca(HCO3)2

Hard water containing calcium bicarbonate loses its carbon dioxide content and precipitates as calcium carbonate-contained by limescale or stalactites.
Ca(HCO3)2 = CaCO3 + H2O + CO2

temperature

temperature

↑↓

↑↓

**Student sheet 8: Softening of hard water**

(type 3: experimental design following a scheme version for Group 3 students)

**Limescale**, a substance that precipitates from **hard water**, forms an insulating coating on the heating elements of washing machines, coffee machines, boilers and kettles. This **increases the energy demand** for heating. Calcium compounds and magnesium compounds, which cause the hardness of water, precipitate with soap and similar detergents. They thus inhibit the **formation of foam** and reduce the **washing effect**. Using **too much soap, detergent, and acidic chemicals to dissolve limescale damages the environment and costs a lot of money**. This is why **water softening** is needed, which we will now look at. How does soap behave in distilled water, which models a soft water, and in mineral water, which models a hard water with a high calcium ion and magnesium ion content? Check out the teacher's experiment!

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

The following table shows the solubility data of salts that can be derived from the ions given. In it, the answer to the question "Soluble?" is "**Good**", meaning that the compound of cation and anion **has good water solubility**, and "**No**", meaning that the precipitate is poorly soluble or **not soluble** at all.

|  |  |
| --- | --- |
| **Cations** | **Anions** |
| OH− | Cl− | S2− | $$SO\_{4}^{2-}$$ | $$PO\_{4}^{3-}$$ | $$CO\_{3}^{2-}$$ | $$NO\_{3}^{-}$$ |
| Na+ | Good | Good | Good | Good | Good | Good | Good |
| K+ | Good | Good | Good | Good | Good | Good | Good |
| Mg2+ | No | Good | Good | Good | No | No | Good |
| Ca2+ | Slightly | Good | Slightly | Slightly | No | No | Good |
| Ba2+ | Good | Good | Good | No | No | No | Good |
| Al3+ | No | Good | − | Good | No | − | Good |
| Zn2+ | No | Good | No | Good | No | No | Good |
| Ag+ | − | No | No | Slightly | No | No | Good |
| Cu2+ | No | Good | No | Good | No | No | Good |
| Pb2+ | No | Slightly | No | No | No | No | Good |
| Fe2+ | No | Good | No | Good | No | No | Good |
| Fe3+ | No | Good | − | Good | No | No | Good |

1. Which **anions form a precipitate** with both the **Ca2+** and **Mg2+**? …………………………….………………………………………………….

2. With which cations form these anions a **water soluble** compound? …………………………………………………….……………………

3. Which 4 compounds do you think are suitable for water softening? ………………………………………………………….………………

4.Of the 4 compounds, "washing soda" and “tribasic”/"trisodium" containing sodium ions are the cheapest solutions. In "trisodium" the "**tri**" means there are 3 cations in the formula. Write their **regular names** and **formula** here!

Formula of tribasic/trisodium: ………………………..name: ………………………………………………………………………

Formula of washing soda: ……………………….. name: ………………………………………………………………………

**Design experiments to check whether tribasic/trisodium and washing soda really soften the water!**

MATERIALS AND EQUIPMENT: mineral water, tribasic/trisodium, washing soda, soap solution, test tube rack, 3 test tubes, 3 rubber stoppers, 2 beakers, measuring cylinder, 2 lab spoons, Pasteur pipette, ruler.

5. WHAT IS THE INDEPENDENT VARIABLE THAT YOU HAVE TO CHANGE IN THE EXPERIMENTS? **YOU ARE ONLY**

**ALLOWED TO CHANGE ONE FACTOR AT A TIME!** ……………………………………………………………………………………………………….

6. WHAT IS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDS ON THE INDEPENDENT VARIABLE?

……………………………………………………………………………………………………………………………………………………………………….……

7. HOW CAN YOU TEST THIS DEPENDENT VARIABLE? ………………………………………..……………………………………………………….

……………………………………………………………………………………………………………………………………………………………………….……

8. THIS IS THE ASSUMPTION (HYPOTHESIS): If ……………………………………………………………………………………………………….

(the independent variable changes as intended), then ………………………………………………………………………………………. (the dependent variable will change in this way).

9. HOW CAN THE INDEPENDENT VARIABLE CHANGE? Plan what to put in each test tubes.

|  |  |  |
| --- | --- | --- |
| Experiment 1 (**control** experiment) | Experiment 2 | Experiment 3 |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

10. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a **x** sign!

[ ]  The volume of the water samples. [ ]  The diameter of the test tubes. [ ]  The concentration of the soap solution.

[ ]  The volume of the soap solution. [ ]  The degree of shaking. [ ]  The ruler used for the measurement.

11. THE STEPS OF THE EXPERIMENTS:

…………………………………………………………………………………………………………………………………………………………………………….

…………………………………………………………………………………………………………………………………………………………………………….

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After the experiments are done, write down your observations. Complete the text by writing the correct words, underlining or framing the correct words or ~~crossing out~~ the incorrect ones.

12. OBSERVATION: ………………………………………………………………………………………………………………………………………………

…………………………………………………………………………………………………………………………………………………………………………….

13. Explanation: ………………………………………………………………………………………………………………………………………………

14. Write down the equations for water softening with tribasic (trisodium phosphate) and washing soda for hard water containing calcium chloride and magnesium chloride.

……………………………………………………………………………………………………………………………………………………………….

……………………………………………………………………………………………………………………………………………………………….

15. CONCLUSION:

Washing soda (Na2CO3) is **suitable/not suitable** for water softening.

Ttribasic (trisodium, Na3PO4) is **suitable/not suitable** for water softening.

Unfortunately, **phosphates** cause algae growth in natural water, so we try to avoid their use. It is therefore better to use **phosphate-free washing powders**. These either contain non-soap-like particles with dual solubility or bind the calcium and magnesium ions with mineral substances (e.g. zeolites).

10. LET’S THINK! According to several websites, the commonly used household baking soda (chemical name: sodium bicarbonate, formula: NaHCO3) is also suitable for water softening. Can it really be used to soften water? Check out the teacher's experiment!

The compounds of calcium and magnesium ions with the bicarbonate ion are **water soluble/precipitates**.

Baking soda (**NaHCO3**) is **suitable/not suitable** for water softening.

The formation of stalactites in limestone caves and the formation of limescale in the homes is chemically similar process, but they take place at different rates. Limestone, stalactites and limescale are all composed mainly of calcium carbonate. What is the chemical process by which stalactites and limescale are formed? Complete the diagram with the missing reaction equations. Circle the vertical arrows pointing upwards if the amount below needs to be increased, or the arrows pointing downwards if it needs to be decreased for the process to take place.

Carbon dioxide dissolves in water and reacts with calcium carbonate in limestone. This converts it to water-soluble calcium bicarbonate, forming hard water.

…………… + …………… + …………… = ……………

Hard water containing calcium bicarbonate loses its carbon dioxide content and precipitates as calcium carbonate-contained by limescale or stalactites.

…………… = …………… + …………… + ……………

temperature

temperature

↑↓

↑↓

**Teacher notes for Student sheet 8: Softening of hard water**

(type 3: experimental design following a scheme version for Group 3 students)

Teachers are kindly asked to encourage their students to answer questions about experiment design by highlighting its usefulness and praising them for thinking well.

**Limescale**, a substance that precipitates from **hard water**, forms an insulating coating on the heating elements of washing machines, coffee machines, boilers and kettles. This **increases the energy demand** for heating. Calcium compounds and magnesium compounds, which cause the hardness of water, precipitate with soap and similar detergents. They thus inhibit the **formation of foam** and reduce the **washing effect**. Using **too much soap, detergent, and acidic chemicals to dissolve limescale damages the environment and costs a lot of money**. This is why **water softening** is needed, which we will now look at. How does soap behave in distilled water, which models a soft water, and in mineral water, which models a hard water with a high calcium ion and magnesium ion content? Check out the teacher's experiment!

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

The following table shows the solubility data of salts that can be derived from the ions given. In it, the answer to the question "Soluble?" is "**Good**", meaning that the compound of cation and anion **has good water solubility**, and "**No**", meaning that the precipitate is poorly soluble or **not soluble** at all.

|  |  |
| --- | --- |
| **Cations** | **Anions** |
| OH− | Cl− | S2− | $$SO\_{4}^{2-}$$ | $$PO\_{4}^{3-}$$ | $$CO\_{3}^{2-}$$ | $$NO\_{3}^{-}$$ |
| Na+ | Good | Good | Good | Good | Good | Good | Good |
| K+ | Good | Good | Good | Good | Good | Good | Good |
| Mg2+ | No | Good | Good | Good | No | No | Good |
| Ca2+ | Slightly | Good | Slightly | Slightly | No | No | Good |
| Ba2+ | Good | Good | Good | No | No | No | Good |
| Al3+ | No | Good | − | Good | No | − | Good |
| Zn2+ | No | Good | No | Good | No | No | Good |
| Ag+ | − | No | No | Slightly | No | No | Good |
| Cu2+ | No | Good | No | Good | No | No | Good |
| Pb2+ | No | Slightly | No | No | No | No | Good |
| Fe2+ | No | Good | No | Good | No | No | Good |
| Fe3+ | No | Good | − | Good | No | No | Good |

1. Which **anions form a precipitate** with both the **Ca2+** and **Mg2+**? The $PO\_{4}^{3-}$ and the $CO\_{3}^{2-}$.

2. With which cations form these anions a **water soluble** compound? With the Na+ and the K+.

3. Which 4 compounds do you think are suitable for water softening? Na2CO3, Na3PO4, K2CO3, K3PO4.

4.Of the 4 compounds, "washing soda" and “tribasic”/"trisodium" containing sodium ions are the cheapest solutions. In "trisodium" the "**tri**" means there are 3 cations in the formula. Write their **regular names** and **formula** here!

Formula of tribasic/trisodium: Na3PO4name: trisodium phosphate

Formula of washing soda: Na2CO3 name: disodium carbonate

**Design experiments to check whether tribasic/trisodium and washing soda really soften the water!**

MATERIALS AND EQUIPMENT: mineral water, tribasic/trisodium, washing soda, soap solution, test tube rack, 3 test tubes, 3 rubber stoppers, 2 beakers, measuring cylinder, 2 lab spoons, Pasteur pipette, ruler.

5. WHAT IS THE INDEPENDENT VARIABLE THAT YOU HAVE TO CHANGE IN THE EXPERIMENTS? **YOU ARE ONLY**

**ALLOWED TO CHANGE ONE FACTOR AT A TIME!** The substance added to the mineral water in addition to the soap solution.

6. WHAT IS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDS ON THE INDEPENDENT VARIABLE?

Hardness of the water sample.

7. HOW CAN YOU TEST THIS DEPENDENT VARIABLE? By measuring the height of the soap foam.

8. THIS IS THE ASSUMPTION (HYPOTHESIS): If trisodium or washing soda is added to the water sample (the independent variable changes as intended), then the hardness of the water is reduced (the dependent variable will change in this way).

9. HOW CAN THE INDEPENDENT VARIABLE CHANGE? Plan what to put in each test tubes.

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):mineral water + soap solution | Experiment 2: mineral water + tribasic (trisodium phosphate) + soap solution | Experiment 3: mineral water + washing soda + soap solution |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

10. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a **x** sign!

[x]  The volume of the water samples. [x]  The diameter of the test tubes. [x]  The concentration of the soap solution.

[x]  The volume of the soap solution. [x]  The degree of shaking. [ ]  The ruler used for the measurement.

11. THE STEPS OF THE EXPERIMENTS:

(1) Measure 5-5 cm3 of mineral water into each of the three numbered tubes.

(2) In the second test tube, a small lab spoonful of tribasic (trisodium phosphate) is sprinkled and dissolved by shaking.

(3) In the third tube, add a small lab spoonful of washing soda and dissolve by shaking.

(4) Add 1-1 cm3 of soap solution to each of the three test tubes.

(5) Plug the test tubes and shake each tube vigorously up and down ten times.

(6) Using a ruler, measure the height of the resulting soap foam.

After the experiments are done, write down your observations. Complete the text by writing the correct words, underlining or framing the correct words or ~~crossing out~~ the incorrect ones.

12. OBSERVATION: The tribasic (trisodium) and washing soda turned the mineral water opalescent. In test tube 1 the foam is about 0 − 1 cm high, in test tube 2 about 5 cm high and in test tube 3 about 3 cm high.

13. Explanation: Phosphate and carbonate ions form a precipitate with calcium and magnesium ions.

14. Write down the equations for water softening with tribasic (trisodium phosphate) and washing soda for hard water containing calcium chloride and magnesium chloride.

CaCl2 + Na2CO3 = CaCO3 + 2 NaClMgCl2 + Na2CO3 = MgCO3 + 2 NaCl

3 CaCl2 + 2 Na3PO4 = Ca3(PO4)2 + 6 NaCl3 MgCl2 + 2 Na3PO4 = Mg3(PO4)2 + 6 NaCl

15. CONCLUSION:

Washing soda (Na2CO3) is **suitable/not suitable** for water softening.

Tribasic (trisodium, Na3PO4) is **suitable/not suitable** for water softening.

Unfortunately, **phosphates** cause algae growth in natural water, so we try to avoid their use. It is therefore better to use **phosphate-free washing powders**. These either contain non-soap-like particles with dual solubility or bind the calcium and magnesium ions with mineral substances (e.g. zeolites).

10. LET’S THINK! According to several websites, the commonly used household baking soda (chemical name: sodium bicarbonate, formula: NaHCO3) is also suitable for water softening. Can it really be used to soften water? Check out the teacher's experiment!

The compounds of calcium and magnesium ions with the bicarbonate ion are **water soluble/precipitates**.

Baking soda (**NaHCO3**) is **suitable/not suitable** for water softening.

The formation of stalactites in limestone caves and the formation of limescale in the homes is chemically similar process, but they take place at different rates. Limestone, stalactites and limescale are all composed mainly of calcium carbonate. What is the chemical process by which stalactites and limescale are formed? Complete the diagram with the missing reaction equations. Circle the vertical arrows pointing upwards if the amount below needs to be increased, or the arrows pointing downwards if it needs to be decreased for the process to take place.

Carbon dioxide dissolves in water and reacts with calcium carbonate in limestone. This converts it to water-soluble calcium bicarbonate, forming hard water.
CaCO3 + H2O + CO2 = Ca(HCO3)2

Hard water containing calcium bicarbonate loses its carbon dioxide content and precipitates as calcium carbonate-contained by limescale or stalactites.
Ca(HCO3)2 = CaCO3 + H2O + CO2

temperature

temperature

↑↓

↑↓

END OF THE 8th STUDENT SHEETS AND TEACHER NOTES

**Student sheet** **9: Is the calcination of lime a combustion?[[9]](#footnote-9)**

(type 1: ‘step-by-step’ version for Group 1 students)

Limestone is a very useful raw material for the construction industry. It can be used both outdoors and indoors to build walls and cladding, and the materials that can be produced from it are also very useful. It is first heated at high temperatures to produce calcinated or quicklime /CaO/, which is then dissolved in water to produce slaked or hydrated lime /Ca(OH)2/. Slaked lime is a highly alkaline substance. These processes take place according to the following chemical reaction equations.

Calcination of lime: CaCO3 = CaO + CO2 and lime slaking: CaO + H2O → Ca(OH)2

Traces of traditional lime calcination (“lime burning”) can still be found in Bükkszentkereszt. The process is heat-absorbing, and the necessary heat and high temperatures are provided by burning wood. The furnace, the so-called lime kiln, has a dome shape and most of it is sunk into the ground.

"A kiln is usually heated for 3-4 days. To get one hundred kilogram weight of quicklime, you need almost two hundred kilogram weight of limestone and about 1.3 cubic metres of wood. Once the kiln is fired, the temperature is continuously increased by adding more and more wood logs. After an initial red glow of the limestone, white glowing begins around 900 °C, and the limestone is calcinated."[[10]](#footnote-10)

So, is calcinating lime a combustion? Justify your answer!

…………………………………………………………………………………………………………………………………………………………………………….

Why is the process called “lime burning”?

…………………………………………………………………………………………………………………………………………………………………………….

What burns in traditional lime calcination and why?

…………………………………………………………………………………………………………………………………………………………………………….

MATERIALS AND EQUIPMENT: distilled water, limestone, other stone, phenolphthalein solution, 3 beakers or glasses, Pasteur pipette, tweezers, alcohol burner, matches.

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):water + phenolphthalein solution | Experiment 2: heating the limestone, then water + phenolphthalein solution+ heated limestone | Experiment 3: heating the other stone, then water + phenolphthalein solution+ heated other stone |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Pour (equal amounts of) distilled water into 3 beakers or glasses.

(2) Drip a few drops of phenolphthalein solution (equal volume) into the 3 beakers or glasses.

(3) Using tweezers, heat the stones over the flame of the alcohol burner for the same amount of time (min. 4 minutes).

(4) After heating the limestone and the other stone, heated limestone is put into the second beaker or glass, and the heated other stone into the third beaker or glass.

(5) After an equal time has elapsed, note the colour of the liquid in the beakers or glasses near the stones.

After the experiments are done, write down your observations, the explanations and the conclusions.

1. OBSERVATION:

1.:…………………………………………………………………………………………………………………………………………………………………………

2.:…………………………………………………………………………………………………………………………………………………………………………

3.:…………………………………………………………………………………………………………………………………………………………………………

2. Explanation:

1.:…………………………………………………………………………………………………………………………………………………………………………

2.:…………………………………………………………………………………………………………………………………………………………………………

3.:………………………………………………………………………………………………………………………………………………………………………

3. CONCLUSION: …………………………………………………………………………………………………………………………………………………..

4. LET’S THINK! The heating of limestone is an endothermic process during which limestone decomposes. It produces quicklime and carbon dioxide. The quicklime can be dissolved in water to produce slaked lime. The resulting slaked lime is mixed with sand and water to form a mortar, which can be used to fix bricks by smoothing them into the mortar or to plaster walls. In both cases, the slaked lime in the mortar binds the carbon dioxide in the air, while it turns to calcium carbonate and produces water.

**Circle the up or down arrows in the diagram that show the change of the given amount.**

↑ ↓

CO2 in the air when calcinating/burning limestone (CaCO3)

↑ ↓

CO2 content of the air during the setting of mortar (/Ca(OH)2/ +sand)

Amount of water (H2O) produced during the formation of plaster (CaCO3+ sand)

↑ ↓

Amount of water used at the time of the formation of slaked lime /Ca(OH)2/

↑ ↓

CaCO3 →CaO + CO2

CaO + H2O → Ca(OH)2

Ca(OH)2 + CO2 → CaCO3 + H2O

The dashed arrow indicates that this step only theoretically leads to a recycling process, as the plaster can no longer be used as lime, as it contains sand. Although efforts are made to recycle as much of the demolished material as possible, the plaster does not fall into this category due to its composition, and therefore ends up in general construction waste and in landfills.

Why was coal burnt in newly plastered buildings in the past?

……………………………………………………………………………………………………………………………………………………………………………

Why do you think walls produce "tears" (drops of water) while plaster dries?

……………………………………………………………………………………………………………………………………………………………………………

**Teacher notes for Student sheet 9: Is the Is the calcination of lime a combustion?[[11]](#footnote-11)**

(type 1: ‘step-by-step’ version for Group 1 students)

Teachers are kindly asked to encourage their students to do experiments by highlighting the importance of experimentation in science and praising them when they think correctly.

Limestone is a very useful raw material for the construction industry. It can be used both outdoors and indoors to build walls and cladding, and the materials that can be produced from it are also very useful. It is first heated at high temperatures to produce calcinated or quicklime /CaO/, which is then dissolved in water to produce slaked or hydrated lime /Ca(OH)2/. Slaked lime is a highly alkaline substance. These processes take place according to the following chemical reaction equations.

Calcination of lime: CaCO3 = CaO + CO2 and lime slaking: CaO + H2O → Ca(OH)2

Traces of traditional lime calcination (“lime burning”) can still be found in Bükkszentkereszt. The process is heat-absorbing, and the necessary heat and high temperatures are provided by burning wood. The furnace, the so-called lime kiln, has a dome shape and most of it is sunk into the ground.

"A kiln is usually heated for 3-4 days. To get one hundred kilogram weight of quicklime, you need almost two hundred kilogram weight of limestone and about 1.3 cubic metres of wood. Once the kiln is fired, the temperature is continuously increased by adding more and more wood logs. After an initial red glow of the limestone, white glowing begins around 900 °C, and the limestone is calcinated."[[12]](#footnote-12)

So, is calcinating lime a combustion? Justify your answer! No, because combustion is a combination with oxygen. This is not what happens here, but calcium carbonate is decomposed by heating.

Why is the process called “lime burning”? Because they used the heat generated by burning wood, but when they named it, they didn't know that the essence of combustion was combining with oxygen.

What burns in traditional lime calcination and why? Wood, because it provides the heat and the right temperature for endothermic lime combustion.

MATERIALS AND EQUIPMENT: distilled water, limestone, other stone, phenolphthalein solution, 3 beakers or glasses, Pasteur pipette, tweezers, alcohol burner, matches.

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):water + phenolphthalein solution | Experiment 2: heating the limestone, then water + phenolphthalein solution+ heated limestone | Experiment 3: heating the other stone, then water + phenolphthalein solution+ heated other stone |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Pour (equal amounts of) distilled water into 3 beakers or glasses.

(2) Drip a few drops of phenolphthalein solution (equal volume) into the 3 beakers or glasses.

(3) Using tweezers, heat the stones over the flame of the alcohol burner for the same amount of time (min. 4 minutes).

(4) After heating the limestone and the other stone, heated limestone is put into the second beaker or glass, and the heated other stone into the third beaker or glass.

(5) After an equal time has elapsed, note the colour of the liquid in the beakers or glasses near the stones.

After the experiments are done, write down your observations, the explanations and the conclusions.

1. OBSERVATION:

1: The aqueous solution is colourless (possibly opalescent due to phenolphthalein).

2: The colour of the aqueous solution is purple.

3: The aqueous solution is colourless (possibly opalescent due to phenolphthalein).

2. Explanation:

1. Distilled water is neutral.

2. The heated limestone (quicklime) reacts with the water to produce an alkaline solution.

3. Heated other stone does not react with water, so the solution remains neutral.

3. CONCLUSION: By heating limestone, additional useful raw material can be obtained, while this does not happen when heating other stones.

4. LET’S THINK! The heating of limestone is an endothermic process during which limestone decomposes. It produces quicklime and carbon dioxide. The quicklime can be dissolved in water to produce slaked lime. The resulting slaked lime is mixed with sand and water to form a mortar, which can be used to fix bricks by smoothing them into the mortar or to plaster walls. In both cases, the slaked lime in the mortar binds the carbon dioxide in the air, while it turns to calcium carbonate and produces water.

**Circle the up or down arrows in the diagram that show the change of the given amount.**

↑ ↓

CO2 in the air when calcinating/burning limestone (CaCO3)

↑ ↓

CO2 content of the air during the setting of mortar (/Ca(OH)2/ +sand)

Amount of water (H2O) produced during the formation of plaster (CaCO3+ sand)

↑ ↓

Amount of water used at the time of the formation of slaked lime /Ca(OH)2/

↑ ↓

CaCO3 →CaO + CO2

CaO + H2O → Ca(OH)2

Ca(OH)2 + CO2 → CaCO3 + H2O

The dashed arrow indicates that this step only theoretically leads to a recycling process, as the plaster can no longer be used as lime, as it contains sand. Although efforts are made to recycle as much of the demolished material as possible, the plaster does not fall into this category due to its composition, and therefore ends up in general construction waste and in landfills.

Why was coal burnt in newly plastered buildings in the past?

The CO2 produced helped the mortar to set.

Why do you think walls produce "tears" (drops of water) while plaster dries?

This is because water is produced during the setting of the mortar.

**Student sheet 9: Is the calcination of lime a combustion?[[13]](#footnote-13)**

(type 2: ‘step-by-step’ version + scheme of experimental design for Group 2 students)

Limestone is a very useful raw material for the construction industry. It can be used both outdoors and indoors to build walls and cladding, and the materials that can be produced from it are also very useful. It is first heated at high temperatures to produce calcinated or quicklime /CaO/, which is then dissolved in water to produce slaked or hydrated lime /Ca(OH)2/. Slaked lime is a highly alkaline substance. These processes take place according to the following chemical reaction equations.

Calcination of lime: CaCO3 = CaO + CO2 and lime slaking: CaO + H2O → Ca(OH)2

Traces of traditional lime calcination (“lime burning”) can still be found in Bükkszentkereszt. The process is heat-absorbing, and the necessary heat and high temperatures are provided by burning wood. The furnace, the so-called lime kiln, has a dome shape and most of it is sunk into the ground.

"A kiln is usually heated for 3-4 days. To get one hundred kilogram weight of quicklime, you need almost two hundred kilogram weight of limestone and about 1.3 cubic metres of wood. Once the kiln is fired, the temperature is continuously increased by adding more and more wood logs. After an initial red glow of the limestone, white glowing begins around 900 °C, and the limestone is calcinated."[[14]](#footnote-14)

So, is calcinating lime a combustion? Justify your answer!

…………………………………………………………………………………………………………………………………………………………………………….

Why is the process called “lime burning”?

…………………………………………………………………………………………………………………………………………………………………………….

What burns in traditional lime calcination and why?

…………………………………………………………………………………………………………………………………………………………………………….

MATERIALS AND EQUIPMENT: distilled water, limestone, other stone, phenolphthalein solution, 3 beakers or glasses, Pasteur pipette, tweezers, alcohol burner, matches.

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):water + phenolphthalein solution | Experiment 2: heating the limestone, then water + phenolphthalein solution+ heated limestone | Experiment 3: heating the other stone, then water + phenolphthalein solution+ heated other stone |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Pour (equal amounts of) distilled water into 3 beakers or glasses.

(2) Drip a few drops of phenolphthalein solution (equal volume) into the 3 beakers or glasses.

(3) Using tweezers, heat the stones over the flame of the alcohol burner for the same amount of time (min. 4 minutes).

(4) After heating the limestone and the other stone, heated limestone is put into the second beaker or glass, and the heated other stone into the third beaker or glass.

(5) After an equal time has elapsed, note the colour of the liquid in the beakers or glasses near the stones.

After the experiments are done, write down your observations, the explanations and the conclusions.

1. OBSERVATION:

1.:…………………………………………………………………………………………………………………………………………………………………………

2.:…………………………………………………………………………………………………………………………………………………………………………

3.:…………………………………………………………………………………………………………………………………………………………………………

2. Explanation:

1.:…………………………………………………………………………………………………………………………………………………………………………

2.:…………………………………………………………………………………………………………………………………………………………………………

3.:………………………………………………………………………………………………………………………………………………………………………

3. CONCLUSION: …………………………………………………………………………………………………………………………………………………..

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

4. WHAT WAS THE INDEPENDENT VARIABLE THAT YOU HAD TO CHANGE IN THE EXPERIMENTS? **YOU ARE ONLY**

**ALLOWED TO CHANGE ONE FACTOR AT A TIME!** ………………………………………………………………………….………………………

5. WHAT WAS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDED ON THE INDEPENDENT VARIABLE?

…………………………………………………………………………………………………………………………………………………………………………….

6. HOW COULD YOU TEST THIS DEPENDENT VARIABLE? ……………………………………………………………………………………….

7. THIS WAS THE ASSUMPTION (HYPOTHESIS):

If ………………………………………………………………………………………………………………………………………. (the independent

variable changes as intended), then ………………………………………………………………………………………. (the dependent variable will change in this way).

8. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a ✚sign!

Which do not have to be the same, mark with ➖!

⬜ Time taken to heat the stones

⬜ Volume of water

⬜ Volume of the glass

⬜ Volume (number of droplets) of phenolphthalein solution

⬜ Quantity/mass of stones

9. LET’S THINK! The heating of limestone is an endothermic process during which limestone decomposes. It produces quicklime and carbon dioxide. The quicklime can be dissolved in water to produce slaked lime. The resulting slaked lime is mixed with sand and water to form a mortar, which can be used to fix bricks by smoothing them into the mortar or to plaster walls. In both cases, the slaked lime in the mortar binds the carbon dioxide in the air, while it turns to calcium carbonate and produces water.

**Circle the up or down arrows in the diagram that show the change of the given amount.**

↑ ↓

CO2 in the air when calcinating/burning limestone (CaCO3)

↑ ↓

CO2 content of the air during the setting of mortar (/Ca(OH)2/ +sand)

Amount of water (H2O) produced during the formation of plaster (CaCO3+ sand)

↑ ↓

Amount of water used at the time of the formation of slaked lime /Ca(OH)2/

↑ ↓

CaCO3 →CaO + CO2

CaO + H2O → Ca(OH)2

Ca(OH)2 + CO2 → CaCO3 + H2O

The dashed arrow indicates that this step only theoretically leads to a recycling process, as the plaster can no longer be used as lime, as it contains sand. Although efforts are made to recycle as much of the demolished material as possible, the plaster does not fall into this category due to its composition, and therefore ends up in general construction waste and in landfills.

Why was coal burnt in newly plastered buildings in the past?

……………………………………………………………………………………………………………………………………………………………………………

Why do you think walls produce "tears" (drops of water) while plaster dries?

……………………………………………………………………………………………………………………………………………………………………………

**Teacher notes for Student sheet 9: Is the calcination of lime a combustion?[[15]](#footnote-15)**

(type 2: ‘step-by-step’ version + scheme of experimental design for Group 2 students)

Teachers are kindly asked to encourage their students to answer questions about experiment design by highlighting its usefulness and praising them for thinking well.

Limestone is a very useful raw material for the construction industry. It can be used both outdoors and indoors to build walls and cladding, and the materials that can be produced from it are also very useful. It is first heated at high temperatures to produce quicklime or calcinated or quicklime /CaO/, which is then dissolved in water to produce slaked or hydrated lime /Ca(OH)2/. Slaked lime is a highly alkaline substance. These processes take place according to the following chemical reaction equations.

Calcination of lime: CaCO3 = CaO + CO2 and lime slaking: CaO + H2O → Ca(OH)2

Traces of traditional lime calcination (“lime burning”) can still be found in Bükkszentkereszt. The process is heat-absorbing, and the necessary heat and high temperatures are provided by burning wood. The furnace, the so-called lime kiln, has a dome shape and most of it is sunk into the ground.

"A kiln is usually heated for 3-4 days. To get one hundred kilogram weight of quicklime, you need almost two hundred kilogram weight of limestone and about 1.3 cubic metres of wood. Once the kiln is fired, the temperature is continuously increased by adding more and more wood logs. After an initial red glow of the limestone, white glowing begins around 900 °C, and the limestone is calcinated."[[16]](#footnote-16)

So, is calcinating lime a combustion? Justify your answer! No, because combustion is a combination with oxygen. This is not what happens here, but calcium carbonate is decomposed by heating.

Why is the process called “lime burning”? Because they used the heat generated by burning wood, but when they named it, they didn't know that the essence of combustion was combining with oxygen.

What burns in traditional lime calcination and why? Wood, because it provides the heat and the right temperature for endothermic lime combustion.

MATERIALS AND EQUIPMENT: distilled water, limestone, other stone, phenolphthalein solution, 3 beakers or glasses, Pasteur pipette, tweezers, alcohol burner, matches.

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):water + phenolphthalein solution | Experiment 2: heating the limestone, then water + phenolphthalein solution+ heated limestone | Experiment 3: heating the other stone, then water + phenolphthalein solution+ heated other stone |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Pour (equal amounts of) distilled water into 3 beakers or glasses.

(2) Drip a few drops of phenolphthalein solution (equal volume) into the 3 beakers or glasses.

(3) Using tweezers, heat the stones over the flame of the alcohol burner for the same amount of time (min. 4 minutes).

(4) After heating the limestone and the other stone, heated limestone is put into the second beaker or glass, and the heated other stone into the third beaker or glass.

(5) After an equal time has elapsed, note the colour of the liquid in the beakers or glasses near the stones.

After the experiments are done, write down your observations, the explanations and the conclusions.

1. OBSERVATION:

1: The aqueous solution is colourless (possibly opalescent due to phenolphthalein).

2: The colour of the aqueous solution is purple.

3: The aqueous solution is colourless (possibly opalescent due to phenolphthalein).

2. Explanation:

1. Distilled water is neutral.

2. The heated limestone (quicklime) reacts with the water to produce an alkaline solution.

3. Heated other stone does not react with water, so the solution remains neutral.

3. CONCLUSION: By heating limestone, additional useful raw material can be obtained, while this does not happen when heating other stones.

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

4. WHAT WAS THE INDEPENDENT VARIABLE THAT YOU HAD TO CHANGE IN THE EXPERIMENTS? **YOU ARE ONLY**

**ALLOWED TO CHANGE ONE FACTOR AT A TIME!** Substance of the stone used in the experiment.

5. WHAT WAS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDED ON THE INDEPENDENT VARIABLE?

Whether the final solution is alkaline or not.

6. HOW COULD YOU TEST THIS DEPENDENT VARIABLE? By the change of colour of phenolphthalein to purple.

7. THIS WAS THE ASSUMPTION (HYPOTHESIS):

If the sample used in the experiment was limestone (the independent variable changes as intended), then the final solution would be alkaline (the dependent variable will change in this way).

8. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a ✚sign!

Which do not have to be the same, mark with ➖!

✚ Time taken to heat the stones

✚ Volume of water

➖ Volume of the glass

✚ Volume (number of droplets) of phenolphthalein solution

➖ Quantity/mass of stones

9. LET’S THINK! The heating of limestone is an endothermic process during which limestone decomposes. It produces quicklime and carbon dioxide. The quicklime can be dissolved in water to produce slaked lime. The resulting slaked lime is mixed with sand and water to form a mortar, which can be used to fix bricks by smoothing them into the mortar or to plaster walls. In both cases, the slaked lime in the mortar binds the carbon dioxide in the air, while it turns to calcium carbonate and produces water.

**Circle the up or down arrows in the diagram that show the change of the given amount.**

↑ ↓

CO2 in the air when calcinating/burning limestone (CaCO3)

↑ ↓

CO2 content of the air during the setting of mortar (/Ca(OH)2/ +sand)

Amount of water (H2O) produced during the formation of plaster (CaCO3+ sand)

↑ ↓

Amount of water used at the time of the formation of slaked lime /Ca(OH)2/

↑ ↓

CaCO3 →CaO + CO2

CaO + H2O → Ca(OH)2

Ca(OH)2 + CO2 → CaCO3 + H2O

The dashed arrow indicates that this step only theoretically leads to a recycling process, as the plaster can no longer be used as lime, as it contains sand. Although efforts are made to recycle as much of the demolished material as possible, the plaster does not fall into this category due to its composition, and therefore ends up in general construction waste and in landfills.

Why was coal burnt in newly plastered buildings in the past?

The CO2 produced helped the mortar to set.

Why do you think walls produce "tears" (drops of water) while plaster dries?

This is because water is produced during the setting of the mortar.

**Student sheet 9: Is the calcination of lime a combustion?[[17]](#footnote-17)**

(type 3: experimental design following a scheme version for Group 3 students)

Limestone is a very useful raw material for the construction industry. It can be used both outdoors and indoors to build walls and cladding, and the materials that can be produced from it are also very useful. It is first heated at high temperatures to produce calcinated or quicklime /CaO/, which is then dissolved in water to produce slaked or hydrated lime /Ca(OH)2/. Slaked lime is a highly alkaline substance. These processes take place according to the following chemical reaction equations.

Calcination of lime: CaCO3 = CaO + CO2 and lime slaking: CaO + H2O → Ca(OH)2

Traces of traditional lime calcination (“lime burning”) can still be found in Bükkszentkereszt. The process is heat-absorbing, and the necessary heat and high temperatures are provided by burning wood. The furnace, the so-called lime kiln, has a dome shape and most of it is sunk into the ground.

"A kiln is usually heated for 3-4 days. To get one hundred kilogram weight of quicklime, you need almost two hundred kilogram weight of limestone and about 1.3 cubic metres of wood. Once the kiln is fired, the temperature is continuously increased by adding more and more wood logs. After an initial red glow of the limestone, white glowing begins around 900 °C, and the limestone is calcinated."[[18]](#footnote-18)

So, is calcinating lime a combustion? Justify your answer!

…………………………………………………………………………………………………………………………………………………………………………….

Why is the process called “lime burning”?

…………………………………………………………………………………………………………………………………………………………………………….

What burns in traditional lime calcination and why?

…………………………………………………………………………………………………………………………………………………………………………….

Design an experiment to decide which of the stones on the trays is limestone!

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

MATERIALS AND EQUIPMENT: distilled water, limestone, other stone, phenolphthalein solution, 3 beakers or glasses, Pasteur pipette, tweezers, alcohol burner, matches.

1. WHAT IS THE INDEPENDENT VARIABLE THAT YOU HAVE TO CHANGE IN THE EXPERIMENTS? **YOU ARE ONLY**

**ALLOWED TO CHANGE ONE FACTOR AT A TIME!** ……………………………………………………………………………………………………….

2. WHAT IS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDS ON THE INDEPENDENT VARIABLE?

……………………………………………………………………………………………………………………………………………………………………….……

3. HOW CAN YOU TEST THIS DEPENDENT VARIABLE? ………………………………………..……………………………………………………….

……………………………………………………………………………………………………………………………………………………………………….……

4. THIS IS THE ASSUMPTION (HYPOTHESIS): If ……………………………………………………………………………………………………….

(the independent variable changes as intended), then ………………………………………………………………………………………. (the dependent variable will change in this way).

5. HOW CAN THE INDEPENDENT VARIABLE CHANGE? Plan what to put in each test beakers/glasses.

|  |  |  |
| --- | --- | --- |
| Experiment 1 (**control** experiment) | Experiment 2 | Experiment 3 |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

6. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a ✚sign!

Which do not have to be the same, mark with ➖!

⬜ Time taken to heat the stones

⬜ Volume of water

⬜ Volume of the glass

⬜ Volume (number of droplets) of phenolphthalein solution

⬜ Quantity/mass of stones

7. THE STEPS OF THE EXPERIMENTS:

…………………………………………………………………………………………………………………………………………………………………………….

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After the experiments are done, write down your observations, the explanations and the conclusions.

8. OBSERVATION:

1.:…………………………………………………………………………………………………………………………………………………………………………

2.:…………………………………………………………………………………………………………………………………………………………………………

3.:…………………………………………………………………………………………………………………………………………………………………………

9. Explanation:

1.:…………………………………………………………………………………………………………………………………………………………………………

2.:…………………………………………………………………………………………………………………………………………………………………………

3.:…………………………………………………………………………………………………………………………………………………………………………

10. CONCLUSION: …………………………………………………………………………………………………………………………………………………

11. LET’S THINK! The heating of limestone is an endothermic process during which limestone decomposes. It produces quicklime and carbon dioxide. The quicklime can be dissolved in water to produce slaked lime. The resulting slaked lime is mixed with sand and water to form a mortar, which can be used to fix bricks by smoothing them into the mortar or to plaster walls. In both cases, the slaked lime in the mortar binds the carbon dioxide in the air, while it turns to calcium carbonate and produces water.

**Circle the up or down arrows in the diagram that show the change of the given amount.**

↑ ↓

CO2 in the air when calcinating/burning limestone (CaCO3)

↑ ↓

CO2 content of the air during the setting of mortar (/Ca(OH)2/ +sand)

Amount of water (H2O) produced during the formation of plaster (CaCO3+ sand)

↑ ↓

Amount of water used at the time of the formation of slaked lime /Ca(OH)2/

↑ ↓

CaCO3 →CaO + CO2

CaO + H2O → Ca(OH)2

Ca(OH)2 + CO2 → CaCO3 + H2O

The dashed arrow indicates that this step only theoretically leads to a recycling process, as the plaster can no longer be used as lime, as it contains sand. Although efforts are made to recycle as much of the demolished material as possible, the plaster does not fall into this category due to its composition, and therefore ends up in general construction waste and in landfills.

Why was coal burnt in newly plastered buildings in the past?

……………………………………………………………………………………………………………………………………………………………………………

Why do you think walls produce "tears" (drops of water) while plaster dries?

……………………………………………………………………………………………………………………………………………………………………………

**Teacher notes for Student sheet 9: Is the calcination of lime a combustion?[[19]](#footnote-19)**

(type 3: experimental design following a scheme version for Group 3 students)

Teachers are kindly asked to encourage their students to answer questions about experiment design by highlighting its usefulness and praising them for thinking well.

Limestone is a very useful raw material for the construction industry. It can be used both outdoors and indoors to build walls and cladding, and the materials that can be produced from it are also very useful. It is first heated at high temperatures to produce calcinated or quicklime /CaO/, which is then dissolved in water to produce slaked or hydrated lime /Ca(OH)2/. Slaked lime is a highly alkaline substance. These processes take place according to the following chemical reaction equations.

Calcination of lime: CaCO3 = CaO + CO2 and lime slaking: CaO + H2O → Ca(OH)2

Traces of traditional lime calcination (“lime burning”) can still be found in Bükkszentkereszt. The process is heat-absorbing, and the necessary heat and high temperatures are provided by burning wood. The furnace, the so-called lime kiln, has a dome shape and most of it is sunk into the ground.

"A kiln is usually heated for 3-4 days. To get one hundred kilogram weight of quicklime, you need almost two hundred kilogram weight of limestone and about 1.3 cubic metres of wood. Once the kiln is fired, the temperature is continuously increased by adding more and more wood logs. After an initial red glow of the limestone, white glowing begins around 900 °C, and the limestone is calcinated."[[20]](#footnote-20)

So, is calcinating lime a combustion? Justify your answer! No, because combustion is a combination with oxygen. This is not what happens here, but calcium carbonate is decomposed by heating.

Why is the process called “lime burning”? Because they used the heat generated by burning wood, but when they named it, they didn't know that the essence of combustion was combining with oxygen.

What burns in traditional lime calcination and why? Wood, because it provides the heat and the right temperature for endothermic lime combustion.

Design an experiment to decide which of the stones on the trays is limestone!

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

MATERIALS AND EQUIPMENT: distilled water, limestone, other stone, phenolphthalein solution, 3 beakers or glasses, Pasteur pipette, tweezers, alcohol burner, matches.

1. WHAT IS THE INDEPENDENT VARIABLE THAT YOU HAVE TO CHANGE IN THE EXPERIMENTS? **YOU ARE ONLY**

**ALLOWED TO CHANGE ONE FACTOR AT A TIME!** Substance of the stone used in the experiment.

2. WHAT IS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDS ON THE INDEPENDENT VARIABLE?

Whether the final solution is alkaline or not.

3. HOW CAN YOU TEST THIS DEPENDENT VARIABLE? By the change of colour of phenolphthalein to purple.

4. THIS IS THE ASSUMPTION (HYPOTHESIS): If the sample used in the experiment is limestone (the independent variable changes as intended), then the final solution would be alkaline (the dependent variable will change in this way).

5. HOW CAN THE INDEPENDENT VARIABLE CHANGE? Plan what to put in each test beakers/glasses.

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):water + phenolphthalein solution | Experiment 2: heating the limestone, then water + phenolphthalein solution+ heated limestone | Experiment 3: heating the other stone, then water + phenolphthalein solution+ heated other stone |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

6. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a ✚sign!

Which do not have to be the same, mark with ➖!

✚ Time taken to heat the stones

✚ Volume of water

➖ Volume of the glass

✚ Volume (number of droplets) of phenolphthalein solution

➖ Quantity/mass of stones

7. THE STEPS OF THE EXPERIMENTS:

(1) Pour (equal amounts of) distilled water into 3 beakers or glasses.

(2) Drip a few drops of phenolphthalein solution (equal volume) into the 3 beakers or glasses.

(3) Using tweezers, heat the stones over the flame of the alcohol burner for the same amount of time (min. 4 minutes).

(4) After heating the limestone and the other stone, heated limestone is put into the second beaker or glass, and the heated other stone into the third beaker or glass.

(5) After an equal time has elapsed, note the colour of the liquid in the beakers or glasses near the stones.

After the experiments are done, write down your observations, the explanations and the conclusions.

8. OBSERVATION:

1: The aqueous solution is colourless (possibly opalescent due to phenolphthalein).

2: The colour of the aqueous solution is purple.

3: The aqueous solution is colourless (possibly opalescent due to phenolphthalein).

9. Explanation:

1. Distilled water is neutral.

2. The heated limestone (quicklime) reacts with the water to produce an alkaline solution.

3. Heated other stone does not react with water, so the solution remains neutral.

10. CONCLUSION: By heating limestone, additional useful raw material can be obtained, while this does not happen when heating other stones.

11. LET’S THINK! The heating of limestone is an endothermic process during which limestone decomposes. It produces quicklime and carbon dioxide. The quicklime can be dissolved in water to produce slaked lime. The resulting slaked lime is mixed with sand and water to form a mortar, which can be used to fix bricks by smoothing them into the mortar or to plaster walls. In both cases, the slaked lime in the mortar binds the carbon dioxide in the air, while it turns to calcium carbonate and produces water.

**Circle the up or down arrows in the diagram that show the change of the given amount.**

↑ ↓

CO2 in the air when calcinating/burning limestone (CaCO3)

↑ ↓

CO2 content of the air during the setting of mortar (/Ca(OH)2/ +sand)

Amount of water (H2O) produced during the formation of plaster (CaCO3+ sand)

↑ ↓

Amount of water used at the time of the formation of slaked lime /Ca(OH)2/

↑ ↓

CaCO3 →CaO + CO2

CaO + H2O → Ca(OH)2

Ca(OH)2 + CO2 → CaCO3 + H2O

The dashed arrow indicates that this step only theoretically leads to a recycling process, as the plaster can no longer be used as lime, as it contains sand. Although efforts are made to recycle as much of the demolished material as possible, the plaster does not fall into this category due to its composition, and therefore ends up in general construction waste and in landfills.

Why was coal burnt in newly plastered buildings in the past?

The CO2 produced helped the mortar to set.

Why do you think walls produce "tears" (drops of water) while plaster dries?

This is because water is produced during the setting of the mortar.

END OF THE 9th STUDENT SHEETS AND TEACHER NOTES

**Student sheet** **10: Does acid rain harm mussels and coral reefs?**

(type 1: ‘step-by-step’ version for Group 1 students)

The formation of acid rain is mainly caused by the following process:

rain becomes more acidic,

its pH ↓

sulphur dioxide dissolves in rainwater

sulphur dioxide is released

into the air

combustion of coal containing sulphur

The essence of the process in chemical equations and words:

S + O2 = SO2 and SO2 + H2O = H2SO3

sulphur + oxygen = sulphur dioxide sulphur dioxide + water = sulphurous **acid**

Acid rain damages plants, especially conifers. The **acid reacts with the** **calcium carbonate content** of limestone sculptures and buildings, slowly destroying them. When acid rain enters natural surface water (e.g. lakes), it turns them **acidic**. It also changes the living conditions of aquatic organisms. You will now investigate this: **does it affect the change of pH of the lake water that is caused by the acid rain** whether the bottom of the lake is made of **limestone or sandstone**?

MATERIALS AND EQUIPMENT: Tap water, pulverized limestone, sand, vinegar, red cabbage juice, 3 glasses, 2 Pasteur pipettes or eye droppers, 2 (lab) spoons.

|  |  |  |
| --- | --- | --- |
| Experiment 1water + red cabbage juice + vinegar | Experiment 2water + red cabbage juice + vinegar **+ sand** | Experiment 2water + red cabbage juice + vinegar **+ limestone** |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

THE STEPS OF THE EXPERIMENTS:

(1) Pour tap water (equal amounts) into the 3 glasses.

(2) Drip red cabbage juice into the 3 glasses (equal amounts).

(3) Drip vinegar (equal quantities) into the 3 glasses.

(4) Add a spoonful of sand to one of the glasses and stir.

(5) Put a spoonful of limestone (with the other spoon) into the other glass and stir.

(6) After an equal time has elapsed, record the colour of the liquid in each glass.

After the experiments are done, write down your observations and explanations.

Also draw a conclusion about the interaction between acid rain and the rock that forms the lake bed.

1. OBSERVATION:

Experiment 1: …………………………………………………………………………………………………………………………………………

Experiment 2: …………………………………………………………………………………………………………………………………………

Experiment 3: …………………………………………………………………………………………………………………………………………

2. Explanation:

Experiment 1: …………………………………………………………………………………………………………………………………………

Experiment 2: …………………………………………………………………………………………………………………………………………

Experiment 3: …………………………………………………………………………………………………………………………………………

3. CONCLUSION: …………………………………………………………………………………………………………………………………………………..

4. LET'S THINK! Limestone is formed from the calcareous skeletons of marine animals. Therefore, calcium carbonate is the main component of limestone and also of the skeleton of calcareous aquatic organisms. How does acid rain affect the living conditions of calcareous animals (e.g. mussels, snails, corals) in natural water?

**Circle the up or down arrows in the diagram that show the change in the given quantity.**

pH of the aquatic habitat

pH of the aquatic habitat

reaction rate of the calcium carbonate+acid

amount of acid in the water of the aquatic habitat

↑↓↓

↑↓

↑↓

↑↓

acid rain

number of animals with calcareous skeleton

**the food chain breaks down**

**combustion**

 **of sulphur-containing carbon**

↑↓

How to prevent the breaking down of the food chain in this system?

……………………………………………………………………………………………………………………………………………………………………………

**Teacher notes for Student sheet 10: Does acid rain harm mussels and coral reefs?**

(type 1: ‘step-by-step’ version for Group 1 students)

Teachers are kindly asked to encourage their students to do experiments by highlighting the importance of experimentation in science and praising them when they think correctly.

The formation of acid rain is mainly caused by the following process:

rain becomes more acidic,

its pH ↓

sulphur dioxide dissolves in rainwater

sulphur dioxide is released

into the air

combustion of coal containing sulphur

The essence of the process in chemical equations and words:

S + O2 = SO2 and SO2 + H2O = H2SO3

sulphur + oxygen = sulphur dioxide sulphur dioxide + water = sulphurous **acid**

Acid rain damages plants, especially conifers. The **acid reacts with the** **calcium carbonate content** of limestone sculptures and buildings, slowly destroying them. When acid rain enters natural surface water (e.g. lakes), it turns them **acidic**. It also changes the living conditions of aquatic organisms. You will now investigate this: **does it affect the change of pH of the lake water that is caused by the acid rain** whether the bottom of the lake is made of **limestone or sandstone**?

MATERIALS AND EQUIPMENT: Tap water, pulverized limestone, sand, vinegar, red cabbage juice, 3 glasses, 2 Pasteur pipettes or eye droppers, 2 (lab) spoons.

|  |  |  |
| --- | --- | --- |
| Experiment 1water + red cabbage juice + vinegar | Experiment 2water + red cabbage juice + vinegar **+ sand** | Experiment 2water + red cabbage juice + vinegar **+ limestone** |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

THE STEPS OF THE EXPERIMENTS:

(1) Pour tap water (equal amounts) into the 3 glasses.

(2) Drip red cabbage juice into the 3 glasses (equal amounts).

(3) Drip vinegar (equal quantities) into the 3 glasses.

(4) Add a spoonful of sand to one of the glasses and stir.

(5) Put a spoonful of limestone (with the other spoon) into the other glass and stir.

(6) After an equal time has elapsed, record the colour of the liquid in each glass.

After the experiments are done, write down your observations and explanations.

Also draw a conclusion about the interaction between acid rain and the rock that forms the lake bed.

1. OBSERVATION:

Experiment 1: The colour of the aqueous solution is pink.

Experiment 2: The colour of the aqueous solution is pink.

Experiment 3: The colour of the aqueous solution is lilac.

2. Explanation:

Experiment 1: The aqueous solution of vinegar is acidic.

Experiment 2: The sand does not react with the (acetic) acid, so the solution remains acidic.

Experiment 3: The limestone reacts with the (acetic) acid in the vinegar. The resulting carbonic acid decomposes into carbon dioxide and water. The carbon dioxide gets off the solution. Thus the acidity of the solution decreases over time.

3. CONCLUSION: Calcareous lake beds can partially neutralise the effect of acid rain.

4. LET'S THINK! Limestone is formed from the calcareous skeletons of marine animals. Therefore, calcium carbonate is the main component of limestone and also of the skeleton of calcareous aquatic organisms. How does acid rain affect the living conditions of calcareous animals (e.g. mussels, snails, corals) in natural water?

**Circle the up or down arrows in the diagram that show the change in the given quantity.**

pH of the aquatic habitat

pH of the aquatic habitat

reaction rate of the calcium carbonate+acid

amount of acid in the water of the aquatic habitat

↑↓

↑↓

↑↓

↑↓

acid rain

number of animals with calcareous skeleton

**the food chain breaks down**

**combustion**

 **of sulphur-containing carbon**

↑↓

How to prevent the breaking down of the food chain in this system?

The formation of acid rain should be prevented by not burning sulphur-containing coal.

**Student sheet** **10: Does acid rain harm mussels and coral reefs?**

(type 2: ‘step-by-step’ version + scheme of experimental design for Group 2 students)

The formation of acid rain is mainly caused by the following process:

rain becomes more acidic,

its pH ↓

sulphur dioxide dissolves in rainwater

sulphur dioxide is released

into the air

combustion of coal containing sulphur

The essence of the process in chemical equations and words:

S + O2 = SO2 and SO2 + H2O = H2SO3

sulphur + oxygen = sulphur dioxide sulphur dioxide + water = sulphurous **acid**

Acid rain damages plants, especially conifers. The **acid reacts with the** **calcium carbonate content** of limestone sculptures and buildings, slowly destroying them. When acid rain enters natural surface water (e.g. lakes), it turns them **acidic**. It also changes the living conditions of aquatic organisms. You will now investigate this: **does it affect the change of pH of the lake water that is caused by the acid rain** whether the bottom of the lake is made of **limestone or sandstone**?

MATERIALS AND EQUIPMENT: Tap water, pulverized limestone, sand, vinegar, red cabbage juice, 3 glasses, 2 Pasteur pipettes or eye droppers, 2 (lab) spoons.

|  |  |  |
| --- | --- | --- |
| Experiment 1water + red cabbage juice + vinegar | Experiment 2water + red cabbage juice + vinegar **+ sand** | Experiment 2water + red cabbage juice + vinegar **+ limestone** |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

THE STEPS OF THE EXPERIMENTS:

(1) Pour tap water (equal amounts) into the 3 glasses.

(2) Drip red cabbage juice into the 3 glasses (equal amounts).

(3) Drip vinegar (equal quantities) into the 3 glasses.

(4) Add a spoonful of sand to one of the glasses and stir.

(5) Put a spoonful of limestone (with the other spoon) into the other glass and stir.

(6) After an equal time has elapsed, record the colour of the liquid in each glass.

After the experiments are done, write down your observations and explanations.

Also draw a conclusion about the interaction between acid rain and the rock that forms the lake bed.

1. OBSERVATION:

Experiment 1: …………………………………………………………………………………………………………………………………………

Experiment 2: …………………………………………………………………………………………………………………………………………

Experiment 3: …………………………………………………………………………………………………………………………………………

2. Explanation:

Experiment 1: …………………………………………………………………………………………………………………………………………

Experiment 2: …………………………………………………………………………………………………………………………………………

Experiment 3: …………………………………………………………………………………………………………………………………………

3. CONCLUSION: …………………………………………………………………………………………………………………………………………………..

|  |  |
| --- | --- |
| **The following had to be substituted** (modelled) in the experiments: | **How could they be replaced** (modelled)? |
| the water of the lake |  |
| the sandy lake bed |  |
| the calcareous lake bed |  |
| acid rain |  |

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

4. WHAT WAS THE INDEPENDENT VARIABLE THAT YOU HAD TO CHANGE IN THE EXPERIMENTS? **YOU ARE ONLY**

**ALLOWED TO CHANGE ONE FACTOR AT A TIME!** ………………………………………………………………………….………………………

5. WHAT WAS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDED ON THE INDEPENDENT VARIABLE?

…………………………………………………………………………………………………………………………………………………………………………….

6. HOW COULD YOU TEST THIS DEPENDENT VARIABLE? ……………………………………………………………………………………….

7. THIS WAS THE ASSUMPTION (HYPOTHESIS):

If ………………………………………………………………………………………………………………………………………. (the independent

variable changes as intended), then ………………………………………………………………………………………. (the dependent variable will change in this way).

8. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a ✚sign!

Which do not have to be the same, mark with ➖!

⬜ Volume of water

⬜ Volume of the glass

⬜ Quantity of sand and limestone

⬜ Time elapsed between addition of sand/limestone and determination of red cabbage juice colour

⬜ Volume of vinegar (number of drops)

⬜ Volume of red cabbage juice

9. LET'S THINK! Limestone is formed from the calcareous skeletons of marine animals. Therefore, calcium carbonate is the main component of limestone and also of the skeleton of calcareous aquatic organisms. How does acid rain affect the living conditions of calcareous animals (e.g. mussels, snails, corals) in natural water?

**Circle the up or down arrows in the diagram that show the change in the given quantity.**

pH of the aquatic habitat

pH of the aquatic habitat

reaction rate of the calcium carbonate+acid

amount of acid in the water of the aquatic habitat

↑↓↓

↑↓

↑↓

↑↓

acid rain

number of animals with calcareous skeleton

**the food chain breaks down**

**combustion**

 **of sulphur-containing carbon**

↑↓

How to prevent the breaking down of the food chain in this system?

……………………………………………………………………………………………………………………………………………………………………………

**Teacher notes for Student sheet 10: Does acid rain harm mussels and coral reefs?**

(type 2: ‘step-by-step’ version + scheme of experimental design for Group 2 students)

Teachers are kindly asked to encourage their students to answer questions about experiment design by highlighting its usefulness and praising them for thinking well.

 The formation of acid rain is mainly caused by the following process:

rain becomes more acidic,

its pH ↓

sulphur dioxide dissolves in rainwater

sulphur dioxide is released

into the air

combustion of coal containing sulphur

The essence of the process in chemical equations and words:

S + O2 = SO2 and SO2 + H2O = H2SO3

sulphur + oxygen = sulphur dioxide sulphur dioxide + water = sulphurous **acid**

Acid rain damages plants, especially conifers. The **acid reacts with the** **calcium carbonate content** of limestone sculptures and buildings, slowly destroying them. When acid rain enters natural surface water (e.g. lakes), it turns them **acidic**. It also changes the living conditions of aquatic organisms. You will now investigate this: **does it affect the change of pH of the lake water that is caused by the acid rain** whether the bottom of the lake is made of **limestone or sandstone**?

MATERIALS AND EQUIPMENT: Tap water, pulverized limestone, sand, vinegar, red cabbage juice, 3 glasses, 2 Pasteur pipettes or eye droppers, 2 (lab) spoons.

|  |  |  |
| --- | --- | --- |
| Experiment 1water + red cabbage juice + vinegar | Experiment 2water + red cabbage juice + vinegar **+ sand** | Experiment 2water + red cabbage juice + vinegar **+ limestone** |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

THE STEPS OF THE EXPERIMENTS:

(1) Pour tap water (equal amounts) into the 3 glasses.

(2) Drip red cabbage juice into the 3 glasses (equal amounts).

(3) Drip vinegar (equal quantities) into the 3 glasses.

(4) Add a spoonful of sand to one of the glasses and stir.

(5) Put a spoonful of limestone (with the other spoon) into the other glass and stir.

(6) After an equal time has elapsed, record the colour of the liquid in each glass.

After the experiments are done, write down your observations and explanations.

Also draw a conclusion about the interaction between acid rain and the rock that forms the lake bed.

1. OBSERVATION:

Experiment 1: The colour of the aqueous solution is pink.

Experiment 2: The colour of the aqueous solution is pink.

Experiment 3: The colour of the aqueous solution is lilac.

2. Explanation:

Experiment 1: The aqueous solution of vinegar is acidic.

Experiment 2: The sand does not react with the (acetic) acid, so the solution remains acidic.

Experiment 3: The limestone reacts with the (acetic) acid in the vinegar. The resulting carbonic acid decomposes into carbon dioxide and water. The carbon dioxide gets off the solution. Thus the acidity of the solution decreases over time.

3. CONCLUSION: Calcareous lake beds can partially neutralise the effect of acid rain.

|  |  |
| --- | --- |
| **The following had to be substituted** (modelled) in the experiments: | **How could they be replaced** (modelled)? |
| the water of the lake | with tap water |
| the sandy lake bed | with sand |
| the calcareous lake bed | with pulverized limestone |
| acid rain | with vinegar |

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

4. WHAT WAS THE INDEPENDENT VARIABLE THAT YOU HAD TO CHANGE IN THE EXPERIMENTS? **YOU ARE ONLY**

**ALLOWED TO CHANGE ONE FACTOR AT A TIME!** The material of the rock forming (modelling) the lake bed.

5. WHAT WAS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDED ON THE INDEPENDENT VARIABLE?

The amount/concentration of acid.

6. HOW COULD YOU TEST THIS DEPENDENT VARIABLE? By the change in the colour of the red cabbage juice.

7. THIS WAS THE ASSUMPTION (HYPOTHESIS):

If the rock forming the lake bed is limestone instead of sand (the independent variable changes as intended), then it increases the pH of the lake water (the dependent variable will change in this way).

8. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a ✚sign!

Which do not have to be the same, mark with ➖!

✚ Volume of water

**(-)** Volume of the glass

✚ Quantity of sand and limestone

✚Time elapsed between addition of sand/limestone and determination of red cabbage juice colour

✚ Volume of vinegar (number of drops)

✚ Volume of red cabbage juice

9. LET'S THINK! Limestone is formed from the calcareous skeletons of marine animals. Therefore, calcium carbonate is the main component of limestone and also of the skeleton of calcareous aquatic organisms. How does acid rain affect the living conditions of calcareous animals (e.g. mussels, snails, corals) in natural water?

**Circle the up or down arrows in the diagram that show the change in the given quantity.**

pH of the aquatic habitat

pH of the aquatic habitat

reaction rate of the calcium carbonate+acid

amount of acid in the water of the aquatic habitat

↑↓

↑↓

↑↓

↑↓

acid rain

number of animals with calcareous skeleton

**the food chain breaks down**

**combustion**

 **of sulphur-containing carbon**

↑↓

How to prevent the breaking down of the food chain in this system?

The formation of acid rain should be prevented by not burning sulphur-containing coal.

**Student sheet 10: Does acid rain harm mussels and coral reefs?**

(type 3: experimental design following a scheme version for Group 3 students)

The formation of acid rain is mainly caused by the following process:

rain becomes more acidic,

its pH ↓

sulphur dioxide dissolves in rainwater

sulphur dioxide is released

into the air

combustion of coal containing sulphur

The essence of the process in chemical equations and words:

S + O2 = SO2 and SO2 + H2O = H2SO3

sulphur + oxygen = sulphur dioxide sulphur dioxide + water = sulphurous **acid**

Acid rain damages plants, especially conifers. The **acid reacts with the** **calcium carbonate content** of limestone sculptures and buildings, slowly destroying them. When acid rain enters natural surface water (e.g. lakes), it turns them **acidic**. It also changes the living conditions of aquatic organisms. You will now investigate this: **does it affect the change of pH of the lake water that is caused by the acid rain** whether the bottom of the lake is made of **limestone or sandstone**?

MATERIALS AND EQUIPMENT: Tap water, pulverized limestone, sand, vinegar, red cabbage juice, 3 glasses, 2 Pasteur pipettes or eye droppers, 2 (lab) spoons.

Choose which materials you can substitute by which substance in the experiment!

|  |  |
| --- | --- |
| **What has to be substituted** (modelled)? | **How could it be replaced** (modelled) in the experiments:? |
| the water of the lake |  |
| the sandy lake bed |  |
| the calcareous lake bed |  |
| acid rain |  |

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

1. WHAT IS THE INDEPENDENT VARIABLE THAT YOU HAVE TO CHANGE IN THE EXPERIMENTS? **YOU ARE ONLY**

**ALLOWED TO CHANGE ONE FACTOR AT A TIME!** ……………………………………………………………………………………………………….

2. WHAT IS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDS ON THE INDEPENDENT VARIABLE?

……………………………………………………………………………………………………………………………………………………………………….……

3. HOW CAN YOU TEST THIS DEPENDENT VARIABLE? ………………………………………..……………………………………………………….

……………………………………………………………………………………………………………………………………………………………………….……

4. THIS IS THE ASSUMPTION (HYPOTHESIS): If ……………………………………………………………………………………………………….

(the independent variable changes as intended), then ………………………………………………………………………………………. (the dependent variable will change in this way).

5. HOW CAN THE INDEPENDENT VARIABLE CHANGE? Plan what to put in each test beakers/glasses.

|  |  |  |
| --- | --- | --- |
| Experiment 1 (**control** experiment) | Experiment 2 | Experiment 3 |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

6. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a ✚sign!

Which do not have to be the same, mark with ➖!

⬜ Volume of water

⬜ Volume of the glass

⬜ Quantity of sand and limestone

⬜ Time elapsed between addition of sand/limestone and determination of red cabbage juice colour

⬜ Volume of vinegar (number of drops)

⬜ Volume of red cabbage juice

7. THE STEPS OF THE EXPERIMENTS:

…………………………………………………………………………………………………………………………………………………………………………….

…………………………………………………………………………………………………………………………………………………………………………….

…………………………………………………………………………………………………………………………………………………………………………….

…………………………………………………………………………………………………………………………………………………………………………….

…………………………………………………………………………………………………………………………………………………………………………….

After the experiments are done, write down your observations and explanations.

Also draw a conclusion about the interaction between acid rain and the rock that forms the lake bed.

8. OBSERVATION:

1.:…………………………………………………………………………………………………………………………………………………………………………

2.:…………………………………………………………………………………………………………………………………………………………………………

3.:…………………………………………………………………………………………………………………………………………………………………………

9. Explanation:

1.:…………………………………………………………………………………………………………………………………………………………………………

2.:…………………………………………………………………………………………………………………………………………………………………………

3.:…………………………………………………………………………………………………………………………………………………………………………

10. CONCLUSION: …………………………………………………………………………………………………………………………………………………

11. LET’S THINK! Limestone is formed from the calcareous skeletons of marine animals. Therefore, calcium carbonate is the main component of limestone and also of the skeleton of calcareous aquatic organisms. How does acid rain affect the living conditions of calcareous animals (e.g. mussels, snails, corals) in natural water?

**Circle the up or down arrows in the diagram that show the change in the given quantity.**

pH of the aquatic habitat

pH of the aquatic habitat

reaction rate of the calcium carbonate+acid

amount of acid in the water of the aquatic habitat

↑↓↓

↑↓

↑↓

↑↓

acid rain

number of animals with calcareous skeleton

**the food chain breaks down**

**combustion**

 **of sulphur-containing carbon**

↑↓

How to prevent the breaking down of the food chain in this system?

……………………………………………………………………………………………………………………………………………………………………………

**Teacher notes for Student sheet 10: Does acid rain harm mussels and coral reefs?**

(type 3: experimental design following a scheme version for Group 3 students)

Teachers are kindly asked to encourage their students to answer questions about experiment design by highlighting its usefulness and praising them for thinking well.

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combustion of coal containing sulphur

The essence of the process in chemical equations and words:

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MATERIALS AND EQUIPMENT: Tap water, pulverized limestone, sand, vinegar, red cabbage juice, 3 glasses, 2 Pasteur pipettes or eye droppers, 2 (lab) spoons.

Choose which materials you can substitute by which substance in the experiment!

|  |  |
| --- | --- |
| **What has to be substituted** (modelled)? | **How could it be replaced** (modelled) in the experiments:? |
| the water of the lake | with tap water |
| the sandy lake bed | with sand |
| the calcareous lake bed | with pulverized limestone |
| acid rain | with vinegar |

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

1. WHAT IS THE INDEPENDENT VARIABLE THAT YOU HAVE TO CHANGE IN THE EXPERIMENTS? **YOU ARE ONLY**

**ALLOWED TO CHANGE ONE FACTOR AT A TIME!** The material of the rock forming (modelling) the lake bed.

2. WHAT IS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDS ON THE INDEPENDENT VARIABLE?

The amount/concentration of acid.

3. HOW CAN YOU TEST THIS DEPENDENT VARIABLE? By the change in the colour of the red cabbage juice.

4. THIS IS THE ASSUMPTION (HYPOTHESIS): If the rock forming the lake bed is limestone instead of sand (the independent variable changes as intended), then it increases the pH of the lake water (the dependent variable will change in this way).

5. HOW CAN THE INDEPENDENT VARIABLE CHANGE? Plan what to put in each test beakers/glasses.

|  |  |  |
| --- | --- | --- |
| Experiment 1water + red cabbage juice + vinegar | Experiment 2water + red cabbage juice + vinegar **+ sand** | Experiment 2water + red cabbage juice + vinegar **+ limestone** |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

6. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a ✚sign!

Which do not have to be the same, mark with ➖!

✚ Volume of water

**(-)** Volume of the glass

✚ Quantity of sand and limestone

✚Time elapsed between addition of sand/limestone and determination of red cabbage juice colour

✚ Volume of vinegar (number of drops)

✚ Volume of red cabbage juice

7. THE STEPS OF THE EXPERIMENTS:

(1) Pour tap water (equal amounts) into the 3 glasses.

(2) Drip red cabbage juice into the 3 glasses (equal amounts).

(3) Drip vinegar (equal quantities) into the 3 glasses.

(4) Add a spoonful of sand to one of the glasses and stir.

(5) Put a spoonful of limestone (with the other spoon) into the other glass and stir.

(6) After an equal time has elapsed, record the colour of the liquid in each glass.

After the experiments are done, write down your observations and explanations.

Also draw a conclusion about the interaction between acid rain and the rock that forms the lake bed.

8. OBSERVATION:

1.: The colour of the aqueous solution is pink.

2.: The colour of the aqueous solution is pink.

3.: The colour of the aqueous solution is lilac.

9. Explanation:

Experiment 1: The aqueous solution of vinegar is acidic.

Experiment 2: The sand does not react with the (acetic) acid, so the solution remains acidic.

Experiment 3: The limestone reacts with the (acetic) acid in the vinegar. The resulting carbonic acid decomposes into carbon dioxide and water. The carbon dioxide gets off the solution. Thus the acidity of the solution decreases over time.

10. CONCLUSION: Calcareous lake beds can partially neutralise the effect of acid rain.

11. LET’S THINK! Limestone is formed from the calcareous skeletons of marine animals. Therefore, calcium carbonate is the main component of limestone and also of the skeleton of calcareous aquatic organisms. How does acid rain affect the living conditions of calcareous animals (e.g. mussels, snails, corals) in natural water?

**Circle the up or down arrows in the diagram that show the change in the given quantity.**

pH of the aquatic habitat

pH of the aquatic habitat

reaction rate of the calcium carbonate+acid

amount of acid in the water of the aquatic habitat

↑↓

↑↓

↑↓

↑↓

acid rain

number of animals with calcareous skeleton

**the food chain breaks down**

**combustion**

 **of sulphur-containing carbon**

↑↓

How to prevent the breaking down of the food chain in this system?

The formation of acid rain should be prevented by not burning sulphur-containing coal.

END OF THE 10th STUDENT SHEETS AND TEACHER NOTES

**Student sheet** **11: Can the topping of a “Dobos” cake[[21]](#footnote-21) be made from birch sugar?**

(type 1: ‘step-by-step’ version for Group 1 students)

The consumption of sugar by people with diabetes should be sharply reduced. To achieve this, granulated sugar can be replaced by sweeteners. Commercially available sweeteners can include saccharin, aspartame, erythritol, stevia, cyclamate, sorbitol, and birch sugar (also known as xylitol). But can they also replace sugar in the caramel topping of a "Dobos" cake? One website says this under a photo of a beautiful "Dobos" cake: *'As there were two persons in the celebrating party who had diabetes, it (this cake) was made with Graham flour and birch sugar to give it a more favourable crime rate :)*' We know that sugars can be caramelized, but is birch sugar really sugar? Can we believe what we read about it on the internet?

MATERIALS AND EQUIPMENT: granulated sugar, glucose, birch sugar (xylitol), 3 test tubes, test-tube rack, alcohol or Bunsen burner, matches, watch glass or ashtray for used matches

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):granulated sugar + heating | Experiment 2: glucose + heating | Experiment 3: birch sugar + heating |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Heat a spoonful of granulated sugar in a test tube until caramelized.

(2) Heat a spoonful of glucose in a test tube for the same amount of time as the granulated sugar.

(3) Heat a spoonful of birch sugar in a test tube for the same time as the granulated sugar.

After the experiments are done, write down your observations and explanations of the experiments.

Also draw a conclusion as to whether birch sugar can be used to make “Dobos” cake.

1. OBSERVATION:

Experiment 1.:………………………………………………………………………………………………………………………………………………………

Experiment 2.:………………………………………………………………………………………………………………………………………………………

Experiment 3.:………………………………………………………………………………………………………………………………………………………

2. Explanation:

Experiment 1.:………………………………………………………………………………………………………………………………………………………

Experiment 2.:………………………………………………………………………………………………………………………………………………………

Experiment 3.:………………………………………………………………………………………………………………………………………………………

3. CONCLUSION: …………………………………………………………………………………………………………………………………………………..

4. LET’S THINK! In diabetes, the kidneys, eyes and nerves can be damaged, wounds heal more slowly and tissues can die. Improper diet, lack of regular exercise and smoking increase the likelihood of developing diabetes. A healthy, hungry person at rest has 3.5 to 6 millimols of glucose per litre of blood. We talk about diabetes when blood glucose levels are significantly above this level. In this case, the patient's carbohydrate intake should be reduced. If this is no longer enough, medication and, in the last resort, insulin will be needed. Insulin lowers blood glucose levels.

Glucose is a basic compound in cell metabolism. It is therefore important to have enough of it available at all times. In times of stress (e.g. when we are frightened and need to act suddenly), the cells use up a lot of glucose from the blood, and blood sugar level drops. The glucose needs to be replaced from the liver. Thus, the living organism has to maintain a sensitive and responsive balance in blood glucose levels (similar to temperature, pH and many other factors).

Based on what you read above, write the following three terms in the appropriate places on the diagram.

1. **stress (e.g. fright) 2. <3,5–6 3. insulin**

Glucose in 1 dm3 blood > 3,5–6 millimol

Glucose in 1 dm3 blood = 3,5–6 millimol

Glucose is transferred from the blood into the cells

Glucose in 1 dm3 blood ………….. millimol

Glucose is released from the liver into the blood

**Teacher notes for Student sheet 11: Can the topping of a “Dobos” cake[[22]](#footnote-22) be made from birch sugar?**

(type 1: ‘step-by-step’ version for Group 1 students)

Teachers are kindly asked to encourage their students to do experiments by highlighting the importance of experimentation in science and praising them when they think correctly.

The consumption of sugar by people with diabetes should be sharply reduced. To achieve this, granulated sugar can be replaced by sweeteners. Commercially available sweeteners can include saccharin, aspartame, erythritol, stevia, cyclamate, sorbitol, and birch sugar (also known as xylitol). But can they also replace sugar in the caramel topping of a "Dobos" cake? One website says this under a photo of a beautiful "Dobos" cake: *'As there were two persons in the celebrating party who had diabetes, it (this cake) was made with Graham flour and birch sugar to give it a more favourable crime rate :)*' We know that sugars can be caramelized, but is birch sugar really sugar? Can we believe what we read about it on the internet?

MATERIALS AND EQUIPMENT: granulated sugar, glucose, birch sugar (xylitol), 3 test tubes, test-tube rack, alcohol or Bunsen burner, matches, watch glass or ashtray for used matches.

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):granulated sugar + heating | Experiment 2: glucose + heating | Experiment 3: birch sugar + heating |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Heat a spoonful of granulated sugar in a test tube until caramelized.

(2) Heat a spoonful of glucose in a test tube for the same amount of time as the granulated sugar.

(3) Heat a spoonful of birch sugar in a test tube for the same time as the granulated sugar.

After the experiments are done, write down your observations and explanations of the experiments.

Also draw a conclusion as to whether birch sugar can be used to make “Dobos” cake.

1. OBSERVATION:

Experiment 1: The granulated sugar melts and forms a caramel with a characteristic colour and smell.

Experiment 2: The glucose melts and forms a caramel with a characteristic colour and smell.

Experiment 3: The birch sugar does not form caramel but melts into a colourless liquid.

2. Explanation:

Experiment 1: Granulated sugar is really sugar.

Experiment 2: Glucose is really sugar.

Experiment 3: Birch sugar is not a sugar, but a substance with a different structure. (Teacher's explanation: Xylitol molecules lack the double bonded carbon and oxygen groups that sugars have.)

3. CONCLUSION: Birch sugar cannot be caramelized because its molecules have a different structure than sugars. A recipe found on the Internet falsely claims that birch sugar can be used to make "Dobos" cake.

4. LET’S THINK! In diabetes, the kidneys, eyes and nerves can be damaged, wounds heal more slowly and tissues can die. Improper diet, lack of regular exercise and smoking increase the likelihood of developing diabetes. A healthy, hungry person at rest has 3.5 to 6 millimols of glucose per litre of blood. We talk about diabetes when blood glucose levels are significantly above this level. In this case, the patient's carbohydrate intake should be reduced. If this is no longer enough, medication and, in the last resort, insulin will be needed. Insulin lowers blood glucose levels.

Glucose is a basic compound in cell metabolism. It is therefore important to have enough of it available at all times. In times of stress (e.g. when we are frightened and need to act suddenly), the cells use up a lot of glucose from the blood, and blood sugar level drops. The glucose needs to be replaced from the liver. Thus, the living organism has to maintain a sensitive and responsive balance in blood glucose levels (similar to temperature, pH and many other factors).

Based on what you read above, write the following three terms in the appropriate places on the diagram.

**1. stress (e.g. fright) 2. <3,5–6 3. insulin**

Glucose in 1 dm3 blood > 3,5–6 millimol

**stress (e.g. fright)**

Glucose in 1 dm3 blood = 3,5–6 millimol

Glucose is transferred from the blood into the cells

Glucose in 1 dm3 blood **<3,5–6** millimol

**insulin**

Glucose is released from the liver into the blood

**Student sheet 11: Can the topping of a “Dobos” cake[[23]](#footnote-23) be made from birch sugar?**

(type 2: ‘step-by-step’ version + scheme of experimental design for Group 2 students)

The consumption of sugar by people with diabetes should be sharply reduced. To achieve this, granulated sugar can be replaced by sweeteners. Commercially available sweeteners can include saccharin, aspartame, erythritol, stevia, cyclamate, sorbitol, and birch sugar (also known as xylitol). But can they also replace sugar in the caramel topping of a "Dobos" cake? One website says this under a photo of a beautiful "Dobos" cake: *'As there were two persons in the celebrating party who had diabetes, it (this cake) was made with Graham flour and birch sugar to give it a more favourable crime rate :)*' We know that sugars can be caramelized, but is birch sugar really sugar? Can we believe what we read about it on the internet?

MATERIALS AND EQUIPMENT: granulated sugar, glucose, birch sugar (xylitol), 3 test tubes, test-tube rack, alcohol or Bunsen burner, matches, watch glass or ashtray for used matches.

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):granulated sugar + heating | Experiment 2: glucose + heating | Experiment 3: birch sugar + heating |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Heat a spoonful of granulated sugar in a test tube until caramelized.

(2) Heat a spoonful of glucose in a test tube for the same amount of time as the granulated sugar.

(3) Heat a spoonful of birch sugar in a test tube for the same time as the granulated sugar.

After the experiments are done, write down your observations and explanations of the experiments.

Also draw a conclusion as to whether birch sugar can be used to make “Dobos” cake.

1. OBSERVATION:

Experiment 1.:………………………………………………………………………………………………………………………………………………………

Experiment 2.:………………………………………………………………………………………………………………………………………………………

Experiment 3.:………………………………………………………………………………………………………………………………………………………

2. Explanation:

Experiment 1.:………………………………………………………………………………………………………………………………………………………

Experiment 2.:………………………………………………………………………………………………………………………………………………………

Experiment 3.:………………………………………………………………………………………………………………………………………………………

3. CONCLUSION: …………………………………………………………………………………………………………………………………………………..

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

4. WHAT WAS THE INDEPENDENT VARIABLE THAT YOU HAD TO CHANGE IN THE EXPERIMENTS? **YOU ARE ONLY**

**ALLOWED TO CHANGE ONE FACTOR AT A TIME!** ………………………………………………………………………….………………………

5. WHAT WAS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDED ON THE INDEPENDENT VARIABLE?

…………………………………………………………………………………………………………………………………………………………………………….

6. HOW COULD YOU TEST THIS DEPENDENT VARIABLE? ……………………………………………………………………………………….

7. THIS WAS THE ASSUMPTION (HYPOTHESIS):

If ………………………………………………………………………………………………………………………………………. (the independent

variable changes as intended), then ………………………………………………………………………………………. (the dependent variable will change in this way).

8. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a ✚sign!

Which do not have to be the same, mark with ➖!

⬜ Amount of the tested substance

⬜ Method of heating

⬜ Volume of the test tube / vessel used for heating

⬜ Time of heating

9. LET'S THINK! In diabetes, the kidneys, eyes and nerves can be damaged, wounds heal more slowly and tissues can die. Improper diet, lack of regular exercise and smoking increase the likelihood of developing diabetes. A healthy, hungry person at rest has 3.5 to 6 millimols of glucose per litre of blood. We talk about diabetes when blood glucose levels are significantly above this level. In this case, the patient's carbohydrate intake should be reduced. If this is no longer enough, medication and, in the last resort, insulin will be needed. Insulin lowers blood glucose levels.

Glucose is a basic compound in cell metabolism. It is therefore important to have enough of it available at all times. In times of stress (e.g. when we are frightened and need to act suddenly), the cells use up a lot of glucose from the blood, and blood sugar level drops. The glucose needs to be replaced from the liver. Thus, the living organism has to maintain a sensitive and responsive balance in blood glucose levels (similar to temperature, pH and many other factors).

Based on what you read above, write the following three terms in the appropriate places on the diagram.

1. **stress (e.g. fright) 2. <3,5–6 3. insulin**

Glucose in 1 dm3 blood > 3,5–6 millimol

Glucose in 1 dm3 blood = 3,5–6 millimol

Glucose is transferred from the blood into the cells

Glucose in 1 dm3 blood ………….. millimol

Glucose is released from the liver into the blood

**Teacher notes for Student sheet 11: Can the topping of a “Dobos” cake[[24]](#footnote-24) be made from birch sugar?**

(type 2: ‘step-by-step’ version + scheme of experimental design for Group 2 students)

Teachers are kindly asked to encourage their students to answer questions about experiment design by highlighting its usefulness and praising them for thinking well.

The consumption of sugar by people with diabetes should be sharply reduced. To achieve this, granulated sugar can be replaced by sweeteners. Commercially available sweeteners can include saccharin, aspartame, erythritol, stevia, cyclamate, sorbitol, and birch sugar (also known as xylitol). But can they also replace sugar in the caramel topping of a "Dobos" cake? One website says this under a photo of a beautiful "Dobos" cake: *'As there were two persons in the celebrating party who had diabetes, it (this cake) was made with Graham flour and birch sugar to give it a more favourable crime rate :)*' We know that sugars can be caramelized, but is birch sugar really sugar? Can we believe what we read about it on the internet?

MATERIALS AND EQUIPMENT: granulated sugar, glucose, birch sugar (xylitol), 3 test tubes, test-tube rack, alcohol or Bunsen burner, matches, watch glass or ashtray for used matches.

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):granulated sugar + heating | Experiment 2: glucose + heating | Experiment 3: birch sugar + heating |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Heat a spoonful of granulated sugar in a test tube until caramelized.

(2) Heat a spoonful of glucose in a test tube for the same amount of time as the granulated sugar.

(3) Heat a spoonful of birch sugar in a test tube for the same time as the granulated sugar.

After the experiments are done, write down your observations and explanations of the experiments.

Also draw a conclusion as to whether birch sugar can be used to make “Dobos” cake.

1. OBSERVATION:

Experiment 1: The granulated sugar melts and forms a caramel with a characteristic colour and smell.

Experiment 2: The glucose melts and forms a caramel with a characteristic colour and smell.

Experiment 3: The birch sugar does not form caramel but melts into a colourless liquid.

2. Explanation:

Experiment 1: Granulated sugar is really sugar.

Experiment 2: Glucose is really sugar.

Experiment 3: Birch sugar is not a sugar, but a substance with a different structure. (Teacher's explanation: Xylitol molecules lack the double bonded carbon and oxygen groups that sugars have.)

3. CONCLUSION: Birch sugar cannot be caramelized because its molecules have a different structure than sugars. A recipe found on the Internet falsely claims that birch sugar can be used to make "Dobos" cake.

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

4. WHAT WAS THE INDEPENDENT VARIABLE THAT YOU HAD TO CHANGE IN THE EXPERIMENTS? **YOU ARE ONLY**

**ALLOWED TO CHANGE ONE FACTOR AT A TIME!** The tested sweet substances.

5. WHAT WAS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDED ON THE INDEPENDENT VARIABLE?

Whether it could be caramelized.

6. HOW COULD YOU TEST THIS DEPENDENT VARIABLE? After heating the substance by sensory examination.

7. THIS WAS THE ASSUMPTION (HYPOTHESIS):

If the tested substance is sugar (the independent variable changes as intended), then at higher temperatures it forms a caramel with a characteristic colour and smell (the dependent variable will change in this way).

8. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a ✚sign!

Which do not have to be the same, mark with ➖!

✚ Amount of the tested substance

✚ Method of heating

**(-)** Volume of the test tube / vessel used for heating

✚ Time of heating

9. LET'S THINK! In diabetes, the kidneys, eyes and nerves can be damaged, wounds heal more slowly and tissues can die. Improper diet, lack of regular exercise and smoking increase the likelihood of developing diabetes. A healthy, hungry person at rest has 3.5 to 6 millimols of glucose per litre of blood. We talk about diabetes when blood glucose levels are significantly above this level. In this case, the patient's carbohydrate intake should be reduced. If this is no longer enough, medication and, in the last resort, insulin will be needed. Insulin lowers blood glucose levels.

Glucose is a basic compound in cell metabolism. It is therefore important to have enough of it available at all times. In times of stress (e.g. when we are frightened and need to act suddenly), the cells use up a lot of glucose from the blood, and blood sugar level drops. The glucose needs to be replaced from the liver. Thus, the living organism has to maintain a sensitive and responsive balance in blood glucose levels (similar to temperature, pH and many other factors).

Based on what you read above, write the following three terms in the appropriate places on the diagram.

**stress (e.g. fright) 2. <3,5–6 3. insulin**

Glucose in 1 dm3 blood > 3,5–6 millimol

**stress (e.g. fright)**

Glucose in 1 dm3 blood = 3,5–6 millimol

Glucose is transferred from the blood into the cells

Glucose in 1 dm3 blood **<3,5–6** millimol

**insulin**

Glucose is released from the liver into the blood

**Student sheet 11: Can the topping of a “Dobos” cake[[25]](#footnote-25) be made from birch sugar?**

(type 3: experimental design following a scheme version for Group 3 students)

The consumption of sugar by people with diabetes should be sharply reduced. To achieve this, granulated sugar can be replaced by sweeteners. Commercially available sweeteners can include saccharin, aspartame, erythritol, stevia, cyclamate, sorbitol, and birch sugar (also known as xylitol). But can they also replace sugar in the caramel topping of a "Dobos" cake? One website says this under a photo of a beautiful "Dobos" cake: *'As there were two persons in the celebrating party who had diabetes, it (this cake) was made with Graham flour and birch sugar to give it a more favourable crime rate :)*' We know that sugars can be caramelized, but is birch sugar really sugar? Can we believe what we read about it on the internet?

MATERIALS AND EQUIPMENT: granulated sugar, glucose, birch sugar (xylitol), 3 test tubes, test-tube rack, alcohol or Bunsen burner, matches, watch glass or ashtray for used matches.

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

1. WHAT IS THE INDEPENDENT VARIABLE THAT YOU HAVE TO CHANGE IN THE EXPERIMENTS? **YOU ARE ONLY**

**ALLOWED TO CHANGE ONE FACTOR AT A TIME!** ……………………………………………………………………………………………………….

2. WHAT IS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDS ON THE INDEPENDENT VARIABLE?

……………………………………………………………………………………………………………………………………………………………………….……

3. HOW CAN YOU TEST THIS DEPENDENT VARIABLE? ………………………………………..……………………………………………………….

……………………………………………………………………………………………………………………………………………………………………….……

4. THIS IS THE ASSUMPTION (HYPOTHESIS): If ……………………………………………………………………………………………………….

(the independent variable changes as intended), then ………………………………………………………………………………………. (the dependent variable will change in this way).

5. HOW CAN THE INDEPENDENT VARIABLE CHANGE? Plan what to put in each test tubes.

|  |  |  |
| --- | --- | --- |
| Experiment 1 (**control** experiment) | Experiment 2 | Experiment 3 |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

6. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a ✚sign!

Which do not have to be the same, mark with ➖!

⬜ Amount of the tested substance

⬜ Method of heating

⬜ Volume of the test tube / vessel used for heating

⬜ Time of heating

7. THE STEPS OF THE EXPERIMENTS:

…………………………………………………………………………………………………………………………………………………………………………….

…………………………………………………………………………………………………………………………………………………………………………….

…………………………………………………………………………………………………………………………………………………………………………….

…………………………………………………………………………………………………………………………………………………………………………….

…………………………………………………………………………………………………………………………………………………………………………….

After the experiments are done, write down your observations and explanations of the experiments.

Also draw a conclusion as to whether birch sugar can be used to make “Dobos” cake.

8. OBSERVATION:

1.:…………………………………………………………………………………………………………………………………………………………………………

2.:…………………………………………………………………………………………………………………………………………………………………………

3.:…………………………………………………………………………………………………………………………………………………………………………

9. Explanation:

1.:…………………………………………………………………………………………………………………………………………………………………………

2.:…………………………………………………………………………………………………………………………………………………………………………

3.:…………………………………………………………………………………………………………………………………………………………………………

10. CONCLUSION: …………………………………………………………………………………………………………………………………………………

11. LET’S THINK! In diabetes, the kidneys, eyes and nerves can be damaged, wounds heal more slowly and tissues can die. Improper diet, lack of regular exercise and smoking increase the likelihood of developing diabetes. A healthy, hungry person at rest has 3.5 to 6 millimols of glucose per litre of blood. We talk about diabetes when blood glucose levels are significantly above this level. In this case, the patient's carbohydrate intake should be reduced. If this is no longer enough, medication and, in the last resort, insulin will be needed. Insulin lowers blood glucose levels.

Glucose is a basic compound in cell metabolism. It is therefore important to have enough of it available at all times. In times of stress (e.g. when we are frightened and need to act suddenly), the cells use up a lot of glucose from the blood, and blood sugar level drops. The glucose needs to be replaced from the liver. Thus, the living organism has to maintain a sensitive and responsive balance in blood glucose levels (similar to temperature, pH and many other factors).

Based on what you read above, write the following three terms in the appropriate places on the diagram.

**1. stress (e.g. fright) 2. <3,5–6 3. insulin**

Glucose in 1 dm3 blood > 3,5–6 millimol

Glucose in 1 dm3 blood = 3,5–6 millimol

Glucose is transferred from the blood into the cells

Glucose in 1 dm3 blood ………….. millimol

Glucose is released from the liver into the blood

**Teacher notes for Student sheet 11: Can the topping of a “Dobos” cake[[26]](#footnote-26) be made from birch sugar?**

(type 3: experimental design following a scheme version for Group 3 students)

Teachers are kindly asked to encourage their students to answer questions about experiment design by highlighting its usefulness and praising them for thinking well.

The consumption of sugar by people with diabetes should be sharply reduced. To achieve this, granulated sugar can be replaced by sweeteners. Commercially available sweeteners can include saccharin, aspartame, erythritol, stevia, cyclamate, sorbitol, and birch sugar (also known as xylitol). But can they also replace sugar in the caramel topping of a "Dobos" cake? One website says this under a photo of a beautiful "Dobos" cake: *'As there were two persons in the celebrating party who had diabetes, it (this cake) was made with Graham flour and birch sugar to give it a more favourable crime rate :)*' We know that sugars can be caramelized, but is birch sugar really sugar? Can we believe what we read about it on the internet?

MATERIALS AND EQUIPMENT: granulated sugar, glucose, birch sugar (xylitol), 3 test tubes, test-tube rack, alcohol or Bunsen burner, matches, watch glass or ashtray for used matches.

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

1. WHAT IS THE INDEPENDENT VARIABLE THAT YOU HAVE TO CHANGE IN THE EXPERIMENTS? **YOU ARE ONLY**

**ALLOWED TO CHANGE ONE FACTOR AT A TIME!** The tested sweet substances.

2. WHAT IS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDS ON THE INDEPENDENT VARIABLE?

Whether it could be caramelized.

3. HOW CAN YOU TEST THIS DEPENDENT VARIABLE? After heating the substance by sensory examination.

4. THIS IS THE ASSUMPTION (HYPOTHESIS): If the tested substance is sugar (the independent variable changes as intended), then at higher temperatures it forms a caramel with a characteristic colour and smell (the dependent variable will change in this way).

5. HOW CAN THE INDEPENDENT VARIABLE CHANGE? Plan what to put in each test tubes.

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):granulated sugar + heating | Experiment 2: glucose + heating | Experiment 3: birch sugar + heating |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

6. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a ✚sign!

Which do not have to be the same, mark with ➖!

✚ Amount of the tested substance

✚ Method of heating

**(-)** Volume of the test tube / vessel used for heating

✚ Time of heating

7. THE STEPS OF THE EXPERIMENTS:

(1) Heat a spoonful of granulated sugar in a test tube until caramelized.

(2) Heat a spoonful of glucose in a test tube for the same amount of time as the granulated sugar.

(3) Heat a spoonful of birch sugar in a test tube for the same time as the granulated sugar.

After the experiments are done, write down your observations and explanations of the experiments.

Also draw a conclusion as to whether birch sugar can be used to make “Dobos” cake.

8. OBSERVATION:

Experiment 1: The granulated sugar melts and forms a caramel with a characteristic colour and smell.

Experiment 2: The glucose melts and forms a caramel with a characteristic colour and smell.

Experiment 3: The birch sugar does not form caramel but melts into a colourless liquid.

9. Explanation:

Experiment 1: Granulated sugar is really sugar.

Experiment 2: Glucose is really sugar.

Experiment 3: Birch sugar is not a sugar, but a substance with a different structure. (Teacher's explanation: Xylitol molecules lack the double bonded carbon and oxygen groups that sugars have.)

10. CONCLUSION: Birch sugar cannot be caramelized because its molecules have a different structure than sugars. A recipe found on the Internet falsely claims that birch sugar can be used to make "Dobos" cake.

11. LET’S THINK! In diabetes, the kidneys, eyes and nerves can be damaged, wounds heal more slowly and tissues can die. Improper diet, lack of regular exercise and smoking increase the likelihood of developing diabetes. A healthy, hungry person at rest has 3.5 to 6 millimols of glucose per litre of blood. We talk about diabetes when blood glucose levels are significantly above this level. In this case, the patient's carbohydrate intake should be reduced. If this is no longer enough, medication and, in the last resort, insulin will be needed. Insulin lowers blood glucose levels.

Glucose is a basic compound in cell metabolism. It is therefore important to have enough of it available at all times. In times of stress (e.g. when we are frightened and need to act suddenly), the cells use up a lot of glucose from the blood, and blood sugar level drops. The glucose needs to be replaced from the liver. Thus, the living organism has to maintain a sensitive and responsive balance in blood glucose levels (similar to temperature, pH and many other factors).

Based on what you read above, write the following three terms in the appropriate places on the diagram.

**1. stress (e.g. fright) 2. <3,5–6 3. insulin**

Glucose in 1 dm3 blood > 3,5–6 millimol

**stress (e.g. fright)**

Glucose in 1 dm3 blood = 3,5–6 millimol

Glucose is transferred from the blood into the cells

Glucose in 1 dm3 blood **<3,5–6** millimol

**insulin**

Glucose is released from the liver into the blood

END OF THE 11th STUDENT SHEETS AND TEACHER NOTES

**Student sheet 12: From superhero to supervillain? - Creating mountains of waste from useful plastics**

(type 1: ‘step-by-step’ version for Group 1 students)

The use of **plastics** has become widespread and, in many cases, irreplaceable. For example, **s**uper**a**bsorbent **p**olymers (abbreviated as "SAP", mainly polyacrylates) used in disposable paper nappies and sanitary pads are now indispensable. These plastics **can absorb up to several hundred times their weight from various water-containing liquids**. They are therefore much more efficient than the textiles or cottons used for these purposes before their appearance.[[27]](#footnote-27)

Carry out the following experiments to find out whether the super absorbent plastics in nappies and pads can absorb more distilled water or urine/blood!

MATERIALS AND EQUIPMENT: 2 beakers (or glasses) with 100-100 cm3 distilled water, 2 beakers (or glasses) with 0.1-0.1 g polyacrylate plastic (SAP), 1 measuring cylinder, 1 glass rod, 1 stand with clamp and ring, 1 glass funnel, 2 filter papers, 1 (lab) spoon, stopwatch/mobile phone with stopwatch function, 1 g sodium chloride.

|  |  |
| --- | --- |
| Experiment 1: (**control** experiment):distilled water + SAP+ filtration | Experiment 2: distilled water + sodium chloride + SAP+ filtration |
| number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Pour (all) the distilled water in one beaker over one batch of SAP and stir with the glass rod for a few minutes (until it thickens no more).

(2) Place the measuring cylinder under the filter funnel, pour the resulting gel into the funnel and filter until no more liquid is dripping off (for a long time).

(3) Measure the volume of drained water.

(4) Dissolve the sodium chloride in the distilled water (in the same volume) in the other beaker and repeat steps (1) to (3) with the solution, taking care that the time available for the liquid to be absorbed is the same.

After the experiments are done, write down your observations, answer the question belonging to the experiment and try to find an explanation for what happened.

1. OBSERVATION:

Experiment 1.:………………………………………………………………………………………………………………………………………………………

Experiment 2.:………………………………………………………………………………………………………………………………………………………

2. Explanation:

Experiment 1.:………………………………………………………………………………………………………………………………………………………

This is possible because the sodium ions trapped in the gel can bind large amounts of water in the form of a hydration shell. This is also why sodium chloride in salty foods causes thirst.

Experiment 2.:………………………………………………………………………………………………………………………………………………………

3. CONCLUSION: …………………………………………………………………………………………………………………………………………………..

…………………………………………………………………………………………………………………………………………………………………………….

4. LET’S THINK! The "International Plastic Free July"[[28]](#footnote-28) campaign aims to **reduce the use of plastic** and find **alternatives** to disposable plastic utensils. Many plastics decompose over **hundreds of years**, and their **disposal** is cumbersome and **environmentally damaging**. Currently, their **recycling efficiency is not high either**. So, most of the plastic waste ends up in landfills or in our natural water.[[29]](#footnote-29) It may happen in your lifetime that there will be more plastic in the seas than fish!

In recent years, more and more women have been using **washable pads** to protect the environment, and more and more parents are opting for **washable nappies**. These products have a number of improvements compared to the old pre-SAP solutions, e.g. they contain different **microfibre**s as absorbent material or natural materials (e.g. **bamboo fibre**s). However, many people question whether they are really environmentally friendly, for example because of the potential for water wastage during washing.

**Fill in the following figure with the missing numbers! Underline or frame the correct words or ~~cross out~~ the incorrect ones.**

Water needed to produce **1 paper nappie**: **30-50 litres when using washable nappies**

 using 5 pieces per day: ………………….. water Water required for **1 washing**: **100 litres**

 weekly ……………………………. water water required for each **daily pre-soak**: **20 litres** **[[30]](#footnote-30)**

based on **three washings** per week: …………. water

Based on 5 disposable nappies a day, ................ nappies per year are sent to landfills, but if you wash nappies

three times a week, it is enough to buy ................ reusable nappies. (Water is also needed to produce the nappies, but this is negligible because of the multiple use.)

Taking these factors into account, using washable nappies as opposed to disposable nappies requires **less/more** water, produces **less/more** waste and is therefore a **more/less environmentally conscious** choice. It also costs less for the household. Of course, using disposable nappies is more convenient for parents, but the price will be paid by the nappy-wearers years down the line. Having considered these, **which would you choose**?

**Teacher notes for Student sheet 12: From superhero to supervillain? - Creating mountains of waste from useful plastics**

(type 1: ‘step-by-step’ version for Group 1 students)

Teachers are kindly asked to encourage their students to do experiments by highlighting the importance of experimentation in science and praising them when they think correctly.

The use of **plastics** has become widespread and, in many cases, irreplaceable. For example, **s**uper**a**bsorbent **p**olymers (abbreviated as "SAP", mainly polyacrylates) used in disposable paper nappies and sanitary pads are now indispensable. These plastics **can absorb up to several hundred times their weight from various water-containing liquids**. They are therefore much more efficient than the textiles or cottons used for these purposes before their appearance.[[31]](#footnote-31)

Carry out the following experiments to find out whether the super absorbent plastics in nappies and pads can absorb more distilled water or urine/blood!

MATERIALS AND EQUIPMENT: 2 beakers (or glasses) with 100-100 cm3 distilled water, 2 beakers (or glasses) with 0.1-0.1 g polyacrylate plastic (SAP), 1 measuring cylinder, 1 glass rod, 1 stand with clamp and ring, 1 glass funnel, 2 filter papers, 1 (lab) spoon, stopwatch/mobile phone with stopwatch function, 1 g sodium chloride.

|  |  |
| --- | --- |
| Experiment 1: (**control** experiment):distilled water + SAP+ filtration | Experiment 2: distilled water + sodium chloride + SAP+ filtration |
| number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Pour (all) the distilled water in one beaker over one batch of SAP and stir with the glass rod for a few minutes (until it thickens no more).

(2) Place the measuring cylinder under the filter funnel, pour the resulting gel into the funnel and filter until no more liquid is dripping off (for a long time).

(3) Measure the volume of drained water.

(4) Dissolve the sodium chloride in the distilled water (in the same volume) in the other beaker and repeat steps (1) to (3) with the solution, taking care that the time available for the liquid to be absorbed is the same.

After the experiments are done, write down your observations, answer the question belonging to the experiment and try to find an explanation for what happened.

1. OBSERVATION:

Experiment 1.: About 72 cm3 of distilled water dripped off during filtration.

Experiment 2.: Approximately 91 cm3 of saline solution dripped off during filtration.

2. Explanation:

Experiment 1.: The SAP bound about 28 cm3, or about 28 g of distilled water. This is about 280 times its own mass.

This is possible because the sodium ions trapped in the gel can bind large amounts of water in the form of a hydration shell. This is also why sodium chloride in salty foods causes thirst.

Experiment 2.: SAP bound about 9 cm3 of water from the saline solution, a smaller amount than it bound from distilled water under the same experimental conditions.

3. CONCLUSION: The solution outside the gel contains sodium ions and chloride ions, which also need water. The water they bind cannot be absorbed by the polymer. Thus, when SAP comes into contact with a saline solution (blood, urine), it can absorb less water than when it comes into contact with pure distilled water.

4. LET’S THINK! The "International Plastic Free July"[[32]](#footnote-32) campaign aims to **reduce the use of plastic** and find **alternatives** to disposable plastic utensils. Many plastics decompose over **hundreds of years**, and their **disposal** is cumbersome and **environmentally damaging**. Currently, their **recycling efficiency is not high either**. So, most of the plastic waste ends up in landfills or in our natural water.[[33]](#footnote-33) It may happen in your lifetime that there will be more plastic in the seas than fish!

In recent years, more and more women have been using **washable pads** to protect the environment, and more and more parents are opting for **washable nappies**. These products have a number of improvements compared to the old pre-SAP solutions, e.g. they contain different **microfibre**s as absorbent material or natural materials (e.g. **bamboo fibre**s). However, many people question whether they are really environmentally friendly, for example because of the potential for water wastage during washing.

**Fill in the following figure with the missing numbers! Underline or frame the correct words or ~~cross out~~ the incorrect ones.**

Water needed to produce **1 paper nappie**: **30-50 litres when using washable nappies**

 using 5 pieces per day: **150-250 litres** water Water required for **1 washing**: **100 litres**

 weekly **1050-1750 litres** water water required for each **daily pre-soak**: **20 litres** **[[34]](#footnote-34)**

based on **three washings** per week: 3x100+7x20=**440** **litres** water

Based on 5 disposable nappies a day, **1825** nappies per year are sent to landfills, but if you wash nappies

three times a week, it is enough to buy **in one wash (7x5)/3≈12 pieces, plus 5 other pieces for the time of washing and drying, for a total of about 17 pieces, with a small margin of 20 pieces** reusable nappies. (Water is also needed to produce the nappies, but this is negligible because of the multiple use.)

Taking these factors into account, using washable nappies as opposed to disposable nappies requires **less~~/more~~** water, produces **less~~/more~~** waste and is therefore a **more~~/less~~ environmentally conscious** choice. It also costs less for the household. Of course, using disposable nappies is more convenient for parents, but the price will be paid by the nappy-wearers years down the line. Having considered these, **which would you choose**?

**Student sheet 12: From superhero to supervillain? - Creating mountains of waste from useful plastics**

(type 2: ‘step-by-step’ version + scheme of experimental design for Group 2 students)

The use of **plastics** has become widespread and, in many cases, irreplaceable. For example, **s**uper**a**bsorbent **p**olymers (abbreviated as "SAP", mainly polyacrylates) used in disposable paper nappies and sanitary pads are now indispensable. These plastics **can absorb up to several hundred times their weight from various water-containing liquids**. They are therefore much more efficient than the textiles or cottons used for these purposes before their appearance.[[35]](#footnote-35)

Carry out the following experiments to find out whether the super absorbent plastics in nappies and pads can absorb more distilled water or urine/blood!

MATERIALS AND EQUIPMENT: 2 beakers (or glasses) with 100-100 cm3 distilled water, 2 beakers (or glasses) with 0.1-0.1 g polyacrylate plastic (SAP), 1 measuring cylinder, 1 glass rod, 1 stand with clamp and ring, 1 glass funnel, 2 filter papers, 1 (lab) spoon, stopwatch/mobile phone with stopwatch function, 1 g sodium chloride.

|  |  |
| --- | --- |
| Experiment 1: (**control** experiment):distilled water + SAP+ filtration | Experiment 2: distilled water + sodium chloride + SAP+ filtration |
| number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Pour (all) the distilled water in one beaker over one batch of SAP and stir with the glass rod for a few minutes (until it thickens no more).

(2) Place the measuring cylinder under the filter funnel, pour the resulting gel into the funnel and filter until no more liquid is dripping off (for a long time).

(3) Measure the volume of drained water.

(4) Dissolve the sodium chloride in the distilled water (in the same volume) in the other beaker and repeat steps (1) to (3) with the solution, taking care that the time available for the liquid to be absorbed is the same.

After the experiments are done, write down your observations, answer the question belonging to the experiment and try to find an explanation for what happened.

1. OBSERVATION:

Experiment 1.:………………………………………………………………………………………………………………………………………………………

Experiment 2.:………………………………………………………………………………………………………………………………………………………

2. Explanation:

Experiment 1.:………………………………………………………………………………………………………………………………………………………

This is possible because the sodium ions trapped in the gel can bind large amounts of water in the form of a hydration shell. This is also why sodium chloride in salty foods causes thirst.

Experiment 2.:………………………………………………………………………………………………………………………………………………………

3. CONCLUSION: …………………………………………………………………………………………………………………………………………………..

…………………………………………………………………………………………………………………………………………………………………………….

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

4. HOW COULD YOU SUBSTITUTE (MODEL) URINE/BLOOD IN THE EXPERIMENT?

……………………………………………………………………………………………………………………………………………………………………………

5. WHAT WAS THE INDEPENDENT VARIABLE THAT YOU HAD TO CHANGE IN THE EXPERIMENTS? **YOU ARE ONLY**

**ALLOWED TO CHANGE ONE FACTOR AT A TIME!** ………………………………………………………………………….………………………

6. HOW DID YOU CHANGE THIS INDEPENDENT VARIABLE?

…………………………………………………………………………………………………………………………………………………………………………….

7. WHAT WAS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDED ON THE INDEPENDENT VARIABLE?

…………………………………………………………………………………………………………………………………………………………………………….

8. HOW COULD YOU TEST THIS DEPENDENT VARIABLE? ……………………………………………………………………………………….

9. THIS WAS THE ASSUMPTION (HYPOTHESIS):

If ………………………………………………………………………………………………………………………………………. (the independent

variable changes as intended), then ………………………………………………………………………………………. (the dependent variable will change in this way).

10. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a ✚sign!

⬜ The mass of polyacrylate (SAP)

⬜ Volume of the beaker (glass)

⬜ Volume of the liquids

⬜ Time available to bind liquids

⬜ Volume of the measuring cylinder.

11. LET'S THINK! The "International Plastic Free July"[[36]](#footnote-36) campaign aims to **reduce the use of plastic** and find **alternatives** to disposable plastic utensils. Many plastics decompose over **hundreds of years**, and their **disposal** is cumbersome and **environmentally damaging**. Currently, their **recycling efficiency is not high either**. So, most of the plastic waste ends up in landfills or in our natural water.[[37]](#footnote-37) It may happen in your lifetime that there will be more plastic in the seas than fish!

In recent years, more and more women have been using **washable pads** to protect the environment, and more and more parents are opting for **washable nappies**. These products have a number of improvements compared to the old pre-SAP solutions, e.g. they contain different **microfibre**s as absorbent material or natural materials (e.g. **bamboo fibre**s). However, many people question whether they are really environmentally friendly, for example because of the potential for water wastage during washing.

**Fill in the following figure with the missing numbers! Underline or frame the correct words or ~~cross out~~ the incorrect ones.**

Water needed to produce **1 paper nappie**: **30-50 litres when using washable nappies**

 using 5 pieces per day: ………………….. water Water required for **1 washing**: **100 litres**

 weekly ……………………………. water water required for each **daily pre-soak**: **20 litres** **[[38]](#footnote-38)**

based on **three washings** per week: …………. water

Based on 5 disposable nappies a day, ................ nappies per year are sent to landfills, but if you wash nappies

three times a week, it is enough to buy ................ reusable nappies. (Water is also needed to produce the nappies, but this is negligible because of the multiple use.)

Taking these factors into account, using washable nappies as opposed to disposable nappies requires **less/more** water, produces **less/more** waste and is therefore a **more/less environmentally conscious** choice. It also costs less for the household. Of course, using disposable nappies is more convenient for parents, but the price will be paid by the nappy-wearers years down the line. Having considered these, **which would you choose**?

**Teacher notes for Student sheet 12: From superhero to supervillain? - Creating mountains of waste from useful plastics**

(type 2: ‘step-by-step’ version + scheme of experimental design for Group 2 students)

Teachers are kindly asked to encourage their students to answer questions about experiment design by highlighting its usefulness and praising them for thinking well.

The use of **plastics** has become widespread and, in many cases, irreplaceable. For example, **s**uper**a**bsorbent **p**olymers (abbreviated as "SAP", mainly polyacrylates) used in disposable paper nappies and sanitary pads are now indispensable. These plastics **can absorb up to several hundred times their weight from various water-containing liquids**. They are therefore much more efficient than the textiles or cottons used for these purposes before their appearance.[[39]](#footnote-39)

Carry out the following experiments to find out whether the super absorbent plastics in nappies and pads can absorb more distilled water or urine/blood!

MATERIALS AND EQUIPMENT: 2 beakers (or glasses) with 100-100 cm3 distilled water, 2 beakers (or glasses) with 0.1-0.1 g polyacrylate plastic (SAP), 1 measuring cylinder, 1 glass rod, 1 stand with clamp and ring, 1 glass funnel, 2 filter papers, 1 (lab) spoon, stopwatch/mobile phone with stopwatch function, 1 g sodium chloride.

|  |  |
| --- | --- |
| Experiment 1: (**control** experiment):distilled water + SAP+ filtration | Experiment 2: distilled water + sodium chloride + SAP+ filtration |
| number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Pour (all) the distilled water in one beaker over one batch of SAP and stir with the glass rod for a few minutes (until it thickens no more).

(2) Place the measuring cylinder under the filter funnel, pour the resulting gel into the funnel and filter until no more liquid is dripping off (for a long time).

(3) Measure the volume of drained water.

(4) Dissolve the sodium chloride in the distilled water (in the same volume) in the other beaker and repeat steps (1) to (3) with the solution, taking care that the time available for the liquid to be absorbed is the same.

After the experiments are done, write down your observations, answer the question belonging to the experiment and try to find an explanation for what happened.

1. OBSERVATION:

Experiment 1.: About 72 cm3 of distilled water dripped off during filtration.

Experiment 2.: Approximately 91 cm3 of saline solution dripped off during filtration.

2. Explanation:

Experiment 1.: The SAP bound about 28 cm3, or about 28 g of distilled water. This is about 280 times its own mass.

This is possible because the sodium ions trapped in the gel can bind large amounts of water in the form of a hydration shell. This is also why sodium chloride in salty foods causes thirst.

Experiment 2.: SAP bound about 9 cm3 of water from the saline solution, a smaller amount than it bound from distilled water under the same experimental conditions.

3. CONCLUSION: The solution outside the gel contains sodium ions and chloride ions, which also need water. The water they bind cannot be absorbed by the polymer. Thus, when SAP comes into contact with a saline solution (blood, urine), it can absorb less water than when it comes into contact with pure distilled water.

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

4. HOW COULD YOU SUBSTITUTE (MODEL) URINE/BLOOD IN THE EXPERIMENT?

With sodium chloride solution/saline solution.

5. WHAT WAS THE INDEPENDENT VARIABLE THAT YOU HAD TO CHANGE IN THE EXPERIMENTS? **YOU ARE ONLY**

**ALLOWED TO CHANGE ONE FACTOR AT A TIME!** The amount of solute in the liquid to be bound (absorbed).

6. HOW DID YOU CHANGE THIS INDEPENDENT VARIABLE? Sodium chloride was dissolved in the distilled water in one beaker (glass).

7. WHAT WAS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDED ON THE INDEPENDENT VARIABLE?

The volume of liquid bound (absorbed).

8. HOW COULD YOU TEST THIS DEPENDENT VARIABLE? By measuring the volume of the unabsorbed (remaining) liquid.

9. THIS WAS THE ASSUMPTION (HYPOTHESIS):

If the polymer must absorb a saline liquid/body fluid instead of distilled water (the independent variable changes as intended), then it changes the amount of water that can be bound (absorbed) (the dependent variable will change in this way).

10. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a ✚sign!

✚ The mass of polyacrylate (SAP)

**–** Volume of the beaker (glass)

✚ Volume of the liquids

✚ Time available to bind liquids

**–** Volume of the measuring cylinder.

11. LET'S THINK! The "International Plastic Free July"[[40]](#footnote-40) campaign aims to **reduce the use of plastic** and find **alternatives** to disposable plastic utensils. Many plastics decompose over **hundreds of years**, and their **disposal** is cumbersome and **environmentally damaging**. Currently, their **recycling efficiency is not high either**. So, most of the plastic waste ends up in landfills or in our natural water.[[41]](#footnote-41) It may happen in your lifetime that there will be more plastic in the seas than fish!

In recent years, more and more women have been using **washable pads** to protect the environment, and more and more parents are opting for **washable nappies**. These products have a number of improvements compared to the old pre-SAP solutions, e.g. they contain different **microfibre**s as absorbent material or natural materials (e.g. **bamboo fibre**s). However, many people question whether they are really environmentally friendly, for example because of the potential for water wastage during washing.

**Fill in the following figure with the missing numbers! Underline or frame the correct words or ~~cross out~~ the incorrect ones.**

Water needed to produce **1 paper nappie**: **30-50 litres when using washable nappies**

 using 5 pieces per day: **150-250 litres** water Water required for **1 washing**: **100 litres**

 weekly **1050-1750 litres** water water required for each **daily pre-soak**: **20 litres** **[[42]](#footnote-42)**

based on **three washings** per week: 3x100+7x20=**440** **litres** water

Based on 5 disposable nappies a day, **1825** nappies per year are sent to landfills, but if you wash nappies

three times a week, it is enough to buy **in one wash (7x5)/3≈12 pieces, plus 5 other pieces for the time of washing and drying, for a total of about 17 pieces, with a small margin of 20 pieces** reusable nappies. (Water is also needed to produce the nappies, but this is negligible because of the multiple use.)

Taking these factors into account, using washable nappies as opposed to disposable nappies requires **less~~/more~~** water, produces **less~~/more~~** waste and is therefore a **more~~/less~~ environmentally conscious** choice. It also costs less for the household. Of course, using disposable nappies is more convenient for parents, but the price will be paid by the nappy-wearers years down the line. Having considered these, **which would you choose**?

**Student sheet 12: From superhero to supervillain? - Creating mountains of waste from useful plastics**

(type 3: experimental design following a scheme version for Group 3 students)

The use of **plastics** has become widespread and, in many cases, irreplaceable. For example, **s**uper**a**bsorbent **p**olymers (abbreviated as "SAP", mainly polyacrylates) used in disposable paper nappies and sanitary pads are now indispensable. These plastics **can absorb up to several hundred times their weight from various water-containing liquids**. They are therefore much more efficient than the textiles or cottons used for these purposes before their appearance.[[43]](#footnote-43)

Design an experiment to find out whether super absorbent plastics in nappies and pads can absorb more distilled water or urine/blood!

MATERIALS AND EQUIPMENT: 2 beakers (or glasses) with 100-100 cm3 distilled water, 2 beakers (or glasses) with 0.1-0.1 g polyacrylate plastic (SAP), 1 measuring cylinder, 1 glass rod, 1 stand with clamp and ring, 1 glass funnel, 2 filter papers, 1 (lab) spoon, stopwatch/mobile phone with stopwatch function, 1 g sodium chloride.

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

1. HOW CAN YOU SUBSTITUTE (MODEL) URINE/BLOOD IN THE EXPERIMENT?

……………………………………………………………………………………………………………………………………………………………………………

2. WHAT IS THE INDEPENDENT VARIABLE THAT YOU HAVE TO CHANGE IN THE EXPERIMENTS? **YOU ARE ONLY**

**ALLOWED TO CHANGE ONE FACTOR AT A TIME!** ……………………………………………………………………………………………………….

3. HOW CAN YOU CHANGE THIS INDEPENDENT VARIABLE?

…………………………………………………………………………………………………………………………………………………………………………….

4. WHAT IS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDS ON THE INDEPENDENT VARIABLE?

……………………………………………………………………………………………………………………………………………………………………….……

5. HOW CAN YOU TEST THIS DEPENDENT VARIABLE? ………………………………………..……………………………………………………….

……………………………………………………………………………………………………………………………………………………………………….……

6. THIS IS THE ASSUMPTION (HYPOTHESIS): If ……………………………………………………………………………………………………….

(the independent variable changes as intended), then ………………………………………………………………………………………. (the dependent variable will change in this way).

7. HOW CAN THE INDEPENDENT VARIABLE CHANGE? Plan what to do in each experiment!

|  |  |
| --- | --- |
| Experiment 1: (**control** experiment): | Experiment 2:  |
| number of repetitions in class: | number of repetitions in class: |

8. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a ✚sign!

⬜ The mass of polyacrylate (SAP)

⬜ Volume of the beaker (glass)

⬜ Volume of the liquids

⬜ Time available to bind liquids

⬜ Volume of the measuring cylinder.

9. THE STEPS OF THE EXPERIMENTS:

…………………………………………………………………………………………………………………………………………………………………………….

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…………………………………………………………………………………………………………………………………………………………………………….

After the experiments are done, write down your observations, answer the question belonging to the experiment and try to find an explanation for what happened.

10. OBSERVATION:

Experiment 1.:………………………………………………………………………………………………………………………………………………………

Experiment 2.:………………………………………………………………………………………………………………………………………………………

11. Explanation:

Experiment 1.:………………………………………………………………………………………………………………………………………………………

This is possible because the sodium ions trapped in the gel can bind large amounts of water in the form of a hydration shell. This is also why sodium chloride in salty foods causes thirst.

Experiment 2.:………………………………………………………………………………………………………………………………………………………

12. CONCLUSION: …………………………………………………………………………………………………………………………………………………

…………………………………………………………………………………………………………………………………………………………………………….

13. LET’S THINK! The "International Plastic Free July"[[44]](#footnote-44) campaign aims to **reduce the use of plastic** and find **alternatives** to disposable plastic utensils. Many plastics decompose over **hundreds of years**, and their **disposal** is cumbersome and **environmentally damaging**. Currently, their **recycling efficiency is not high either**. So, most of the plastic waste ends up in landfills or in our natural water.[[45]](#footnote-45) It may happen in your lifetime that there will be more plastic in the seas than fish!

In recent years, more and more women have been using **washable pads** to protect the environment, and more and more parents are opting for **washable nappies**. These products have a number of improvements compared to the old pre-SAP solutions, e.g. they contain different **microfibre**s as absorbent material or natural materials (e.g. **bamboo fibre**s). However, many people question whether they are really environmentally friendly, for example because of the potential for water wastage during washing.

**Fill in the following figure with the missing numbers! Underline or frame the correct words or ~~cross out~~ the incorrect ones.**

Water needed to produce **1 paper nappie**: **30-50 litres when using washable nappies**

 using 5 pieces per day: ………………….. water water required for **1 washing**: **100 litres**

 weekly ……………………………. water water required for each **daily pre-soak**: **20 litres** **[[46]](#footnote-46)**

based on **three washings** per week: …………. water

Based on 5 disposable nappies a day, ................ nappies per year are sent to landfills, but if you wash nappies

three times a week, it is enough to buy ................ reusable nappies. (Water is also needed to produce the nappies, but this is negligible because of the multiple use.)

Taking these factors into account, using washable nappies as opposed to disposable nappies requires **less/more** water, produces **less/more** waste and is therefore a **more/less environmentally conscious** choice. It also costs less for the household. Of course, using disposable nappies is more convenient for parents, but the price will be paid by the nappy-wearers years down the line. Having considered these, **which would you choose**?

**Teacher notes for Student sheet 12: From superhero to supervillain? - Creating mountains of waste from useful plastics**

(type 3: experimental design following a scheme version for Group 3 students)

Teachers are kindly asked to encourage their students to answer questions about experiment design by highlighting its usefulness and praising them for thinking well.

The use of **plastics** has become widespread and, in many cases, irreplaceable. For example, **s**uper**a**bsorbent **p**olymers (abbreviated as "SAP", mainly polyacrylates) used in disposable paper nappies and sanitary pads are now indispensable. These plastics **can absorb up to several hundred times their weight from various water-containing liquids**. They are therefore much more efficient than the textiles or cottons used for these purposes before their appearance.[[47]](#footnote-47)

Design an experiment to find out whether super absorbent plastics in nappies and pads can absorb more distilled water or urine/blood!

MATERIALS AND EQUIPMENT: 2 beakers (or glasses) with 100-100 cm3 distilled water, 2 beakers (or glasses) with 0.1-0.1 g polyacrylate plastic (SAP), 1 measuring cylinder, 1 glass rod, 1 stand with clamp and ring, 1 glass funnel, 2 filter papers, 1 (lab) spoon, stopwatch/mobile phone with stopwatch function, 1 g sodium chloride.

**In real science, evidence is gathered through well-designed experiments. To avoid being misled by pseudo-scientific hoaxes, it's good to understand how to design an experiment correctly. To do this, answer the following questions.**

1. HOW CAN YOU SUBSTITUTE (MODEL) URINE/BLOOD IN THE EXPERIMENT?

With sodium chloride solution/saline solution.

2. WHAT IS THE INDEPENDENT VARIABLE THAT YOU HAVE TO CHANGE IN THE EXPERIMENTS? **YOU ARE ONLY**

**ALLOWED TO CHANGE ONE FACTOR AT A TIME!** The amount of solute in the liquid to be bound (absorbed).

3. HOW CAN YOU CHANGE THIS INDEPENDENT VARIABLE?

Sodium chloride has to be dissolved in the distilled water in one beaker (glass).

4. WHAT IS THE DEPENDENT VARIABLE WHOSE CHANGE DEPENDS ON THE INDEPENDENT VARIABLE?

The volume of liquid bound (absorbed).

5. HOW CAN YOU TEST THIS DEPENDENT VARIABLE? By measuring the volume of the unabsorbed (remaining) liquid.

6. THIS IS THE ASSUMPTION (HYPOTHESIS): If the polymer must absorb a saline liquid/body fluid instead of distilled water (the independent variable changes as intended), then it changes the amount of water that can be bound (absorbed) (the dependent variable will change in this way).

7. HOW CAN THE INDEPENDENT VARIABLE CHANGE? Plan what to do in each experiment!

|  |  |
| --- | --- |
| Experiment 1: (**control** experiment):distilled water + SAP+ filtration | Experiment 2: distilled water + sodium chloride + SAP+ filtration |
| number of repetitions in class: | number of repetitions in class: |

8. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with a ✚sign!

✚ The mass of polyacrylate (SAP)

**–** Volume of the beaker (glass)

✚ Volume of the liquids

✚ Time available to bind liquids

**–** Volume of the measuring cylinder.

9. THE STEPS OF THE EXPERIMENTS:

(1) Pour (all) the distilled water in one beaker over one batch of SAP and stir with the glass rod for a few minutes (until it thickens no more).

(2) Place the measuring cylinder under the filter funnel, pour the resulting gel into the funnel and filter until no more liquid is dripping off (for a long time).

(3) Measure the volume of drained water.

(4) Dissolve the sodium chloride in the distilled water (in the same volume) in the other beaker and repeat steps (1) to (3) with the solution, taking care that the time available for the liquid to be absorbed is the same.

After the experiments are done, write down your observations, answer the question belonging to the experiment and try to find an explanation for what happened.

10. OBSERVATION:

Experiment 1.: About 72 cm3 of distilled water dripped off during filtration.

Experiment 2.: Approximately 91 cm3 of saline solution dripped off during filtration.

11. Explanation:

Experiment 1.: The SAP bound about 28 cm3, or about 28 g of distilled water. This is about 280 times its own mass.

This is possible because the sodium ions trapped in the gel can bind large amounts of water in the form of a hydration shell. This is also why sodium chloride in salty foods causes thirst.

Experiment 2.: SAP bound about 9 cm3 of water from the saline solution, a smaller amount than it bound from distilled water under the same experimental conditions.

3. CONCLUSION: The solution outside the gel contains sodium ions and chloride ions, which also need water. The water they bind cannot be absorbed by the polymer. Thus, when SAP comes into contact with a saline solution (blood, urine), it can absorb less water than when it comes into contact with pure distilled water.

13. LET’S THINK! The "International Plastic Free July"[[48]](#footnote-48) campaign aims to **reduce the use of plastic** and find **alternatives** to disposable plastic utensils. Many plastics decompose over **hundreds of years**, and their **disposal** is cumbersome and **environmentally damaging**. Currently, their **recycling efficiency is not high either**. So, most of the plastic waste ends up in landfills or in our natural water.[[49]](#footnote-49) It may happen in your lifetime that there will be more plastic in the seas than fish!

In recent years, more and more women have been using **washable pads** to protect the environment, and more and more parents are opting for **washable nappies**. These products have a number of improvements compared to the old pre-SAP solutions, e.g. they contain different **microfibre**s as absorbent material or natural materials (e.g. **bamboo fibre**s). However, many people question whether they are really environmentally friendly, for example because of the potential for water wastage during washing.

**Fill in the following figure with the missing numbers! Underline or frame the correct words or ~~cross out~~ the incorrect ones.**

Water needed to produce **1 paper nappie**: **30-50 litres when using washable nappies**

 using 5 pieces per day: ………………….. water water required for **1 washing**: **100 litres**

 weekly ……………………………. water water required for each **daily pre-soak**: **20 litres** **[[50]](#footnote-50)**

based on **three washings** per week: …………. water

Based on 5 disposable nappies a day, ................ nappies per year are sent to landfills, but if you wash nappies

three times a week, it is enough to buy ................ reusable nappies. (Water is also needed to produce the nappies, but this is negligible because of the multiple use.)

Taking these factors into account, using washable nappies as opposed to disposable nappies requires **less/more** water, produces **less/more** waste and is therefore a **more/less environmentally conscious** choice. It also costs less for the household. Of course, using disposable nappies is more convenient for parents, but the price will be paid by the nappy-wearers years down the line. Having considered these, **which would you choose**?

END OF THE 12th STUDENT SHEETS AND TEACHER NOTES

1. The direct translation of the Hungarian expression of the calcining lime is „lime combustion” or „lime burning”. [↑](#footnote-ref-1)
2. „Dobos” cake is a famous cake known by all children in Hungary. Its topping is made of shiny caramel. [↑](#footnote-ref-2)
3. Tóth Péter: Bél Mátyás és a bányavárosok <https://www.academia.edu/6112799/B%C3%A9l_M%C3%A1ty%C3%A1s_%C3%A9s_a_b%C3%A1nyav%C3%A1rosok_In_Tanulm%C3%A1nyk%C3%B6tet_Heckenast_Guszt%C3%A1v_eml%C3%A9k%C3%A9re_Miskolc_2001_126_134_p> last visited: 2022. 08. 14. [↑](#footnote-ref-3)
4. Tóth Péter: Bél Mátyás és a bányavárosok <https://www.academia.edu/6112799/B%C3%A9l_M%C3%A1ty%C3%A1s_%C3%A9s_a_b%C3%A1nyav%C3%A1rosok_In_Tanulm%C3%A1nyk%C3%B6tet_Heckenast_Guszt%C3%A1v_eml%C3%A9k%C3%A9re_Miskolc_2001_126_134_p> last visited: 2022. 08. 14. [↑](#footnote-ref-4)
5. Tóth Péter: Bél Mátyás és a bányavárosok <https://www.academia.edu/6112799/B%C3%A9l_M%C3%A1ty%C3%A1s_%C3%A9s_a_b%C3%A1nyav%C3%A1rosok_In_Tanulm%C3%A1nyk%C3%B6tet_Heckenast_Guszt%C3%A1v_eml%C3%A9k%C3%A9re_Miskolc_2001_126_134_p> last visited: 2022. 08. 14. [↑](#footnote-ref-5)
6. Tóth Péter: Bél Mátyás és a bányavárosok <https://www.academia.edu/6112799/B%C3%A9l_M%C3%A1ty%C3%A1s_%C3%A9s_a_b%C3%A1nyav%C3%A1rosok_In_Tanulm%C3%A1nyk%C3%B6tet_Heckenast_Guszt%C3%A1v_eml%C3%A9k%C3%A9re_Miskolc_2001_126_134_p> last visited: 2022. 08. 14. [↑](#footnote-ref-6)
7. Tóth Péter: Bél Mátyás és a bányavárosok <https://www.academia.edu/6112799/B%C3%A9l_M%C3%A1ty%C3%A1s_%C3%A9s_a_b%C3%A1nyav%C3%A1rosok_In_Tanulm%C3%A1nyk%C3%B6tet_Heckenast_Guszt%C3%A1v_eml%C3%A9k%C3%A9re_Miskolc_2001_126_134_p> last visited: 2022. 08. 14. [↑](#footnote-ref-7)
8. Tóth Péter: Bél Mátyás és a bányavárosok <https://www.academia.edu/6112799/B%C3%A9l_M%C3%A1ty%C3%A1s_%C3%A9s_a_b%C3%A1nyav%C3%A1rosok_In_Tanulm%C3%A1nyk%C3%B6tet_Heckenast_Guszt%C3%A1v_eml%C3%A9k%C3%A9re_Miskolc_2001_126_134_p> last visited: 2022. 08. 14. [↑](#footnote-ref-8)
9. The direct translation of the Hungarian expression of the calcining lime is „lime combustion” or „lime burning”. [↑](#footnote-ref-9)
10. <https://bukkszentkereszt.hu/meszegetes-2/> [↑](#footnote-ref-10)
11. The direct translation of the Hungarian expression of the calcination of lime is „lime combustion” or „lime burning”. [↑](#footnote-ref-11)
12. <https://bukkszentkereszt.hu/meszegetes-2/> [↑](#footnote-ref-12)
13. The direct translation of the Hungarian expression of the calcination of lime is „lime combustion” or „lime burning”. [↑](#footnote-ref-13)
14. <https://bukkszentkereszt.hu/meszegetes-2/> [↑](#footnote-ref-14)
15. The direct translation of the Hungarian expression of the calcination of lime is „lime combustion” or „lime burning”. [↑](#footnote-ref-15)
16. <https://bukkszentkereszt.hu/meszegetes-2/> [↑](#footnote-ref-16)
17. The direct translation of the Hungarian expression of the calcination of lime is „lime combustion” or „lime burning”. [↑](#footnote-ref-17)
18. <https://bukkszentkereszt.hu/meszegetes-2/> [↑](#footnote-ref-18)
19. The direct translation of the Hungarian expression of the calcination of lime is „lime combustion” or „lime burning”. [↑](#footnote-ref-19)
20. <https://bukkszentkereszt.hu/meszegetes-2/> [↑](#footnote-ref-20)
21. „Dobos” cake is a famous cake known by all children in Hungary. Its topping is made of shiny caramel. [↑](#footnote-ref-21)
22. „Dobos” cake is a famous cake known by all children in Hungary. Its topping is made of shiny caramel. [↑](#footnote-ref-22)
23. “Dobos” cake is a famous cake known by all children in Hungary. Its topping is made of shiny caramel. [↑](#footnote-ref-23)
24. “Dobos” cake is a famous cake known by all children in Hungary. Its topping is made of shiny caramel. [↑](#footnote-ref-24)
25. “Dobos” cake is a famous cake known by all children in Hungary. Its topping is made of shiny caramel. [↑](#footnote-ref-25)
26. “Dobos” cake is a famous cake known by all children in Hungary. Its topping is made of shiny caramel. [↑](#footnote-ref-26)
27. <https://quattroplast.hu/muanyagipariszemle/2006/02/szuperabszorbens-polimerek-sap-01.pdf> (last visited: 18. 07. 2022.) [↑](#footnote-ref-27)
28. <https://www.plasticfreejuly.org/> (last visited: 18. 07. 2022.) [↑](#footnote-ref-28)
29. <https://www.origo.hu/tudomany/20170701-percenkent-egymillio-muanyagpalackot-adnak-el-vilagszerte.html> (last visited: 18. 07. 2022.) [↑](#footnote-ref-29)
30. <https://mosipopi.hu/mosipopi-kisokos/> (last visited: 25. 07. 2022.) [↑](#footnote-ref-30)
31. <https://quattroplast.hu/muanyagipariszemle/2006/02/szuperabszorbens-polimerek-sap-01.pdf> (last visited: 18. 07. 2022.) [↑](#footnote-ref-31)
32. <https://www.plasticfreejuly.org/> (last visited: 18. 07. 2022.) [↑](#footnote-ref-32)
33. <https://www.origo.hu/tudomany/20170701-percenkent-egymillio-muanyagpalackot-adnak-el-vilagszerte.html> (last visited: 18. 07. 2022.) [↑](#footnote-ref-33)
34. <https://mosipopi.hu/mosipopi-kisokos/> (last visited: 25. 07. 2022.) [↑](#footnote-ref-34)
35. <https://quattroplast.hu/muanyagipariszemle/2006/02/szuperabszorbens-polimerek-sap-01.pdf> (last visited: 18. 07. 2022.) [↑](#footnote-ref-35)
36. <https://www.plasticfreejuly.org/> (last visited: 18. 07. 2022.) [↑](#footnote-ref-36)
37. <https://www.origo.hu/tudomany/20170701-percenkent-egymillio-muanyagpalackot-adnak-el-vilagszerte.html> (last visited: 18. 07. 2022.) [↑](#footnote-ref-37)
38. <https://mosipopi.hu/mosipopi-kisokos/> (last visited: 25. 07. 2022.) [↑](#footnote-ref-38)
39. <https://quattroplast.hu/muanyagipariszemle/2006/02/szuperabszorbens-polimerek-sap-01.pdf> (last visited: 18. 07. 2022.) [↑](#footnote-ref-39)
40. <https://www.plasticfreejuly.org/> (last visited: 18. 07. 2022.) [↑](#footnote-ref-40)
41. <https://www.origo.hu/tudomany/20170701-percenkent-egymillio-muanyagpalackot-adnak-el-vilagszerte.html> (last visited: 18. 07. 2022.) [↑](#footnote-ref-41)
42. <https://mosipopi.hu/mosipopi-kisokos/> (last visited: 25. 07. 2022.) [↑](#footnote-ref-42)
43. <https://quattroplast.hu/muanyagipariszemle/2006/02/szuperabszorbens-polimerek-sap-01.pdf> (last visited: 18. 07. 2022.) [↑](#footnote-ref-43)
44. <https://www.plasticfreejuly.org/> (last visited: 18. 07. 2022.) [↑](#footnote-ref-44)
45. <https://www.origo.hu/tudomany/20170701-percenkent-egymillio-muanyagpalackot-adnak-el-vilagszerte.html> (last visited: 18. 07. 2022.) [↑](#footnote-ref-45)
46. <https://mosipopi.hu/mosipopi-kisokos/> (last visited: 25. 07. 2022.) [↑](#footnote-ref-46)
47. <https://quattroplast.hu/muanyagipariszemle/2006/02/szuperabszorbens-polimerek-sap-01.pdf> (last visited: 18. 07. 2022.) [↑](#footnote-ref-47)
48. <https://www.plasticfreejuly.org/> (last visited: 18. 07. 2022.) [↑](#footnote-ref-48)
49. <https://www.origo.hu/tudomany/20170701-percenkent-egymillio-muanyagpalackot-adnak-el-vilagszerte.html> (last visited: 18. 07. 2022.) [↑](#footnote-ref-49)
50. <https://mosipopi.hu/mosipopi-kisokos/> (last visited: 25. 07. 2022.) [↑](#footnote-ref-50)