**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 (2023/2024.)**

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 13: **Exploding colours**](https://ttomc.elte.hu/rails/active_storage/blobs/eyJfcmFpbHMiOnsibWVzc2FnZSI6IkJBaHBBZ1lRIiwiZXhwIjpudWxsLCJwdXIiOiJibG9iX2lkIn19--70f4634963f571f04c9c7ff3592f3b750e74a4af/13_Langfestes_2024_07_18_HONLAPRA.docx?disposition=attachment)

[Student sheet 14: **Can you walk on water?**](https://ttomc.elte.hu/rails/active_storage/blobs/eyJfcmFpbHMiOnsibWVzc2FnZSI6IkJBaHBBZ2NRIiwiZXhwIjpudWxsLCJwdXIiOiJibG9iX2lkIn19--b2d1f8e17525533cb7b883cdab7873303a9b048f/14_Anyagi_halmazok_2024_07_18_HONLAPRA.docx?disposition=attachment)

[Student sheet 15: **The superglue and others**](https://ttomc.elte.hu/rails/active_storage/blobs/eyJfcmFpbHMiOnsibWVzc2FnZSI6IkJBaHBBZ2dRIiwiZXhwIjpudWxsLCJwdXIiOiJibG9iX2lkIn19--106d5b2eb857b4fbb73d51850c2dfe577559b0d5/15_Reakciosebesseg_2024_07_18_HONLAPRA.docx?disposition=attachment)

[Student sheet 16: **Geyser in a bottle – the Mentos-Cola story**](https://ttomc.elte.hu/rails/active_storage/blobs/eyJfcmFpbHMiOnsibWVzc2FnZSI6IkJBaHBBZ2tRIiwiZXhwIjpudWxsLCJwdXIiOiJibG9iX2lkIn19--2c557e53041ba5ce58a03bbeb60b80d64655912c/16_Egyensulyok_2024_07_18_HONLAPRA.docx?disposition=attachment)

[Student sheet 17: **Sour as vinegar**](https://ttomc.elte.hu/rails/active_storage/blobs/eyJfcmFpbHMiOnsibWVzc2FnZSI6IkJBaHBBZ29RIiwiZXhwIjpudWxsLCJwdXIiOiJibG9iX2lkIn19--bd744b3ca4ef6953f58ef28dfc33f07e8b03fa37/17_Sav-bazis-reakcio_2024_07_18_HONLAPRA.docx?disposition=attachment)

[Student sheet 18: **Hydrogen peroxide as a "miracle cure"?**](https://ttomc.elte.hu/rails/active_storage/blobs/eyJfcmFpbHMiOnsibWVzc2FnZSI6IkJBaHBBZ3NRIiwiZXhwIjpudWxsLCJwdXIiOiJibG9iX2lkIn19--a2f8c1a384d01535db2adaaf7d5fc0f0efa23871/18_Redoxi_2024_07_18_HONLAPRA.docx?disposition=attachment)

**Student sheet 13: Exploding colours**

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

Birthday? New Year's Eve? Olympics? Wedding? Whatever the occasion, fireworks are the highlight of the celebration. With the knowledge and technology of our time, we can create fireworks in countless different colours and shapes, but would you think that it would not exist without a 2,000-year-old coincidence? In ancient China, pieces of bamboo were burnt and exploded due to their hollow structure, believed to ward off evil spirits. This was the predecessor of fireworks. It took almost 1000 years for the first real fireworks with gunpowder to be invented, and almost another millennium for the Italians to colour the sky with lights. Here you will discover the background to these different colour phenomena.

The **most stable** energy state of an atom is called the **ground state**. In this state, the electrons of the atom are arranged in the lowest possible energy atomic orbitals. But when energy is applied (for example, when a substance is heated), **the electrons move to higher energy orbitals**, i.e. the atom enters an **excited state**. This state **is not stable**, so the atom will soon return to the ground state while **radiating the energy it has absorbed**. The energy difference between the ground state and the excited state is called the **excitation energy**.

MATERIALS AND EQUIPMENT: 1 mol/dm3 hydrochloric acid in beakers, solid NaCl in a screw cap (for plastic bottles), 1. unknown salt in a screw cap, 2. unknown salt in a screw cap, iron wire with cork stopper, alcohol/gas burner, matches

**Experiment I.:** Light the alcohol/gas burner. Immerse the end of the iron wire that you find on your tray in the hydrochloric acid (HCl solution) and then in the solid sodium chloride (NaCl). Hold the salt-coated end of the wire in the flame and observe the phenomenon.

**Observation:** The colour of the flame is ........................................................ due to the sodium chloride.

**Explanation:** The metal ion in the salt is atomized by heating, and its electrons are placed in an atomic orbital

with .................................... energy. When the ................................... state is broken, the atom radiated the

energy it had absorbed in the form of ................................... and got back into the ...............................................

The colours of fireworks are also caused by this process. What is the reason why fireworks can be every colour of the rainbow? The **excitation energy** is constant **for atoms of a given element**. This is why the **photons of the electromagnetic waves emitted have the same energy**. When the energy of these photons falls in the **visible light range (380-750 nm)**, we see **the colour of the flame that is characteristic of the atom**. Different metal salts are used to colour fireworks, in which metal ions are responsible for the flame colouring.

The colour of the flame depends on the wavelength of the electromagnetic radiation emitted (its symbol is **). The shorter the wavelength of the light, the closer the colour detected is to violet:

|  |  |
| --- | --- |
| **The colour of the flame** | **Wavelength, *λ* (nm)** |
| violet | 380 – 420 |
| blue | 420 – 490 |
| green | 490 – 575 |
| yellow | 575 – 585 |
| orange | 585 – 650 |
| red | 650 – 750 |

Different electromagnetic radiations differ not only in their wavelengths, but also in the energy of their photons. **The energy of a photon of radiation is inversely proportional to its wavelength**:

$$E\~\frac{1}{λ}$$

**Experiment II.:** Do the following experiments with the other two unknown salts:

|  |  |
| --- | --- |
| Experiment II. aRepeat experiment I. with unknown metal salt 1. | Experiment II. bRepeat experiment II. with unknown metal salt 2. |

THE STEPS OF THE EXPERIMENTS:

II. a: (1) Immerse the iron wire in the hydrochloric acid.

(2) Put the iron wire in the salt 1.

(3) Hold the iron wire in the flame.

II. b: (1) Immerse the iron wire in the hydrochloric acid.

(2) Put the iron wire in the salt 2.

(3) Hold the iron wire in the flame.

**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 II. a: …………………………………………………………………………………………………………………………………………………..

Experiment II. b: ………………………………………………………………………………………………………………………………………………….

2. Explanation:

Experiment II. a: The wavelength corresponding to the excitation energy of the metal atom of the unknown

metal salt 1 falls in the ....................... nm range.

Experiment II. b: The wavelength corresponding to the excitation energy of the metal atom of the unknown

metal salt 2 falls in the ....................... nm range.

3. CONCLUSION: The excitation energy of the metal atom of **unknown salt 1 / unknown salt 2** is less than the excitation energy of sodium, and the excitation energy of the metal atom of **unknown salt 1 / unknown salt 2** is greater.

4. LET'S THINK!

Although fireworks are an eye-catching sight, the different components and principles of operation make them much more dangerous than they first appear. When it explodes, it produces air pollutants (various gases and smoke, the latter including highly dangerous metals responsible for the colouring) which are suddenly released into the air in large quantities and can be harmful even to healthy adults. In addition to the biological side effects of fireworks, the possible physical side effects of sudden sound and light phenomena (stress, hearing loss, fear in animals, confusion) and possible injuries caused by improper use must also be taken into account. In addition, the amount of money spent on a fireworks show at different events is a matter of constant debate. Therefore, before using fireworks to add colour to a celebration, it is worth considering the advantages, disadvantages and possible alternatives (music and light displays etc.)

**Group the particles with the following symbols and formulae according to the role they play in the use of fireworks!** **C, SO2,Li+,** $NO\_{3}^{-}$**, Fe, O2,** $ClO\_{3}^{-}$**, NO2, S, K**+

|  |  |  |  |
| --- | --- | --- | --- |
| combustible material | combustion promoters | substance responsible for the colour effect | air polluting combustion products |
|  |  |  |  |

**Teacher notes for Student sheet 13: Exploding colours**

(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.

Birthday? New Year's Eve? Olympics? Wedding? Whatever the occasion, fireworks are the highlight of the celebration. With the knowledge and technology of our time, we can create fireworks in countless different colours and shapes, but would you think that it would not exist without a 2,000-year-old coincidence? In ancient China, pieces of bamboo were burnt and exploded due to their hollow structure, believed to ward off evil spirits. This was the predecessor of fireworks. It took almost 1000 years for the first real fireworks with gunpowder to be invented, and almost another millennium for the Italians to colour the sky with lights. Here you will discover the background to these different colour phenomena.

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MATERIALS AND EQUIPMENT: 1 mol/dm3 hydrochloric acid in beakers, solid NaCl in a screw cap (for plastic bottles), 1. unknown salt in a screw cap, 2. unknown salt in a screw cap, iron wire with cork stopper, alcohol/gas burner, matches

**Experiment I.:** Light the alcohol/gas burner. Immerse the end of the iron wire that you find on your tray in the hydrochloric acid (HCl solution) and then in the solid sodium chloride (NaCl). Hold the salt-coated end of the wire in the flame and observe the phenomenon.

**Observation:** The colour of the flame is yellow due to the sodium chloride.

**Explanation:** The metal ion in the salt is atomized by heating, and its electrons are placed in an atomic orbital

with higher energy. When the excitation state is broken, the atom radiated the

energy it had absorbed in the form of yellow light and got back into the ground state.

The colours of fireworks are also caused by this process. What is the reason why fireworks can be every colour of the rainbow? The **excitation energy** is constant **for atoms of a given element**. This is why the **photons of the electromagnetic waves emitted have the same energy**. When the energy of these photons falls in the **visible light range (380-750 nm)**, we see **the colour of the flame that is characteristic of the atom**. Different metal salts are used to colour fireworks, in which metal ions are responsible for the flame colouring.

The colour of the flame depends on the wavelength of the electromagnetic radiation emitted (its symbol is **). The shorter the wavelength of the light, the closer the colour detected is to violet:

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| --- | --- |
| **The colour of the flame** | **Wavelength, *λ* (nm)** |
| violet | 380 – 420 |
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**Experiment II.:** Do the following experiments with the other two unknown salts:

|  |  |
| --- | --- |
| Experiment II. aRepeat experiment I. with unknown metal salt 1. | Experiment II. bRepeat experiment II. with unknown metal salt 2. |

THE STEPS OF THE EXPERIMENTS:

II. a: (1) Immerse the iron wire in the hydrochloric acid.

(2) Put the iron wire in the salt 1.

(3) Hold the iron wire in the flame.

II. b: (1) Immerse the iron wire in the hydrochloric acid.

(2) Put the iron wire in the salt 2.

(3) Hold the iron wire in the flame.

**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 II. a: The colour of the flame is brick red.

Experiment II. b: The colour of the flame is green.

2. Explanation:

Experiment II. a: The wavelength corresponding to the excitation energy of the metal atom of the unknown

metal salt 1 falls in the 650 – 750 nm range.

Experiment II. b: The wavelength corresponding to the excitation energy of the metal atom of the unknown

metal salt 2 falls in the 490 – 575 nm range.

3. CONCLUSION: The excitation energy of the metal atom of **unknown salt 1 / unknown salt 2** is less than the excitation energy of sodium, and the excitation energy of the metal atom of **unknown salt 1 / unknown salt 2** is greater.

4. LET'S THINK!

Although fireworks are an eye-catching sight, the different components and principles of operation make them much more dangerous than they first appear. When it explodes, it produces air pollutants (various gases and smoke, the latter including highly dangerous metals responsible for the colouring) which are suddenly released into the air in large quantities and can be harmful even to healthy adults. In addition to the biological side effects of fireworks, the possible physical side effects of sudden sound and light phenomena (stress, hearing loss, fear in animals, confusion) and possible injuries caused by improper use must also be taken into account. In addition, the amount of money spent on a fireworks show at different events is a matter of constant debate. Therefore, before using fireworks to add colour to a celebration, it is worth considering the advantages, disadvantages and possible alternatives (music and light displays etc.)

**Group the particles with the following symbols and formulae according to the role they play in the use of fireworks!** **C, SO2,Li+,** $NO\_{3}^{-}$**, Fe, O2,** $ClO\_{3}^{-}$**, NO2, S, K**+

|  |  |  |  |
| --- | --- | --- | --- |
| combustible material | combustion promoters | substance responsible for the colour effect | air polluting combustion products |
| CFeS | O2$$NO\_{3}^{-}$$$$ClO\_{3}^{-}$$ | Li+K+ | SO2NO2 |

**Student sheet 13: Exploding colours**

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

Birthday? New Year's Eve? Olympics? Wedding? Whatever the occasion, fireworks are the highlight of the celebration. With the knowledge and technology of our time, we can create fireworks in countless different colours and shapes, but would you think that it would not exist without a 2,000-year-old coincidence? In ancient China, pieces of bamboo were burnt and exploded due to their hollow structure, believed to ward off evil spirits. This was the predecessor of fireworks. It took almost 1000 years for the first real fireworks with gunpowder to be invented, and almost another millennium for the Italians to colour the sky with lights. Here you will discover the background to these different colour phenomena.

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**Observation:** The colour of the flame is ........................................................ due to the sodium chloride.

**Explanation:** The metal ion in the salt is atomized by heating, and its electrons are placed in an atomic orbital

with .................................... energy. When the ................................... state is broken, the atom radiated the

energy it had absorbed in the form of ................................... and got back into the ...............................................

The colours of fireworks are also caused by this process. What is the reason why fireworks can be every colour of the rainbow? The **excitation energy** is constant **for atoms of a given element**. This is why the **photons of the electromagnetic waves emitted have the same energy**. When the energy of these photons falls in the **visible light range (380-750 nm)**, we see **the colour of the flame that is characteristic of the atom**. Different metal salts are used to colour fireworks, in which metal ions are responsible for the flame colouring.

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| --- | --- |
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**Experiment II.:** Do the following experiments with the other two unknown salts:

|  |  |
| --- | --- |
| Experiment II. aRepeat experiment I. with unknown metal salt 1. | Experiment II. bRepeat experiment II. with unknown metal salt 2. |

THE STEPS OF THE EXPERIMENTS:

II. a: (1) Immerse the iron wire in the hydrochloric acid.

(2) Put the iron wire in the salt 1.

(3) Hold the iron wire in the flame.

II. b: (1) Immerse the iron wire in the hydrochloric acid.

(2) Put the iron wire in the salt 2.

(3) Hold the iron wire in the flame.

**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 II. a: …………………………………………………………………………………………………………………………………………………..

Experiment II. b: ………………………………………………………………………………………………………………………………………………….

2. Explanation:

Experiment II. a: The wavelength corresponding to the excitation energy of the metal atom of the unknown

metal salt 1 falls in the ....................... nm range.

Experiment II. b: The wavelength corresponding to the excitation energy of the metal atom of the unknown

metal salt 2 falls in the ....................... nm range.

3. CONCLUSION: The excitation energy of the metal atom of **unknown salt 1 / unknown salt 2** is less than the excitation energy of sodium, and the excitation energy of the metal atom of **unknown salt 1 / unknown salt 2** is greater.

**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!

Amount of salt on the metal wire

Concentration of hydrochloric acid

Temperature of hydrochloric acid

Flame temperature

Time to keep it in the flame

9. LET'S THINK!

Although fireworks are an eye-catching sight, the different components and principles of operation make them much more dangerous than they first appear. When it explodes, it produces air pollutants (various gases and smoke, the latter including highly dangerous metals responsible for the colouring) which are suddenly released into the air in large quantities and can be harmful even to healthy adults. In addition to the biological side effects of fireworks, the possible physical side effects of sudden sound and light phenomena (stress, hearing loss, fear in animals, confusion) and possible injuries caused by improper use must also be taken into account. In addition, the amount of money spent on a fireworks show at different events is a matter of constant debate. Therefore, before using fireworks to add colour to a celebration, it is worth considering the advantages, disadvantages and possible alternatives (music and light displays etc.)

**Group the particles with the following symbols and formulae according to the role they play in the use of fireworks!** **C, SO2,Li+,** $NO\_{3}^{-}$**, Fe, O2,** $ClO\_{3}^{-}$**, NO2, S, K**+

|  |  |  |  |
| --- | --- | --- | --- |
| combustible material | combustion promoters | substance responsible for the colour effect | air polluting combustion products |
|  |  |  |  |

**Teacher notes for Student sheet 13: Exploding colours**

(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.

Birthday? New Year's Eve? Olympics? Wedding? Whatever the occasion, fireworks are the highlight of the celebration. With the knowledge and technology of our time, we can create fireworks in countless different colours and shapes, but would you think that it would not exist without a 2,000-year-old coincidence? In ancient China, pieces of bamboo were burnt and exploded due to their hollow structure, believed to ward off evil spirits. This was the predecessor of fireworks. It took almost 1000 years for the first real fireworks with gunpowder to be invented, and almost another millennium for the Italians to colour the sky with lights. Here you will discover the background to these different colour phenomena.

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MATERIALS AND EQUIPMENT: 1 mol/dm3 hydrochloric acid in beakers, solid NaCl in a screw cap (for plastic bottles), 1. unknown salt in a screw cap, 2. unknown salt in a screw cap, iron wire with cork stopper, alcohol/gas burner, matches

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**Observation:** The colour of the flame is yellow due to the sodium chloride.

**Explanation:** The metal ion in the salt is atomized by heating, and its electrons are placed in an atomic orbital

with higher energy. When the excitation state is broken, the atom radiated the

energy it had absorbed in the form of yellow light and got back into the ground state.

The colours of fireworks are also caused by this process. What is the reason why fireworks can be every colour of the rainbow? The **excitation energy** is constant **for atoms of a given element**. This is why the **photons of the electromagnetic waves emitted have the same energy**. When the energy of these photons falls in the **visible light range (380-750 nm)**, we see **the colour of the flame that is characteristic of the atom**. Different metal salts are used to colour fireworks, in which metal ions are responsible for the flame colouring.

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| --- | --- |
| **The colour of the flame** | **Wavelength, *λ* (nm)** |
| violet | 380 – 420 |
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Different electromagnetic radiations differ not only in their wavelengths, but also in the energy of their photons. **The energy of a photon of radiation is inversely proportional to its wavelength**:

$$E\~\frac{1}{λ}$$

**Experiment II.:** Do the following experiments with the other two unknown salts:

|  |  |
| --- | --- |
| Experiment II. aRepeat experiment I. with unknown metal salt 1. | Experiment II. bRepeat experiment II. with unknown metal salt 2. |

THE STEPS OF THE EXPERIMENTS:

II. a: (1) Immerse the iron wire in the hydrochloric acid.

(2) Put the iron wire in the salt 1.

(3) Hold the iron wire in the flame.

II. b: (1) Immerse the iron wire in the hydrochloric acid.

(2) Put the iron wire in the salt 2.

(3) Hold the iron wire in the flame.

**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 II. a: The colour of the flame is brick red.

Experiment II. b: The colour of the flame is green.

2. Explanation:

Experiment II. a: The wavelength corresponding to the excitation energy of the metal atom of the unknown

metal salt 1 falls in the 650 – 750 nm range.

Experiment II. b: The wavelength corresponding to the excitation energy of the metal atom of the unknown

metal salt 2 falls in the 490 – 575 nm range.

3. CONCLUSION: The excitation energy of the metal atom of **unknown salt 1 / unknown salt 2** is less than the excitation energy of sodium, and the excitation energy of the metal atom of **unknown salt 1 / unknown salt 2** is greater.

**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 metal salts.

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

The excitation energy and the colour of the flame and the wavelength of the light emitted.

6. HOW COULD YOU TEST THIS DEPENDENT VARIABLE?

By observing the colour of the flame test.

7. THIS WAS THE ASSUMPTION (HYPOTHESIS):

If the metal salts changes (the independent variable changes as intended), then the excitation energy and thus the wavelength of the flame colour changes (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!

Amount of salt on the metal wire

Concentration of hydrochloric acid

Temperature of hydrochloric acid

[x]  Flame temperature

Time to keep it in the flame

9. LET'S THINK!

Although fireworks are an eye-catching sight, the different components and principles of operation make them much more dangerous than they first appear. When it explodes, it produces air pollutants (various gases and smoke, the latter including highly dangerous metals responsible for the colouring) which are suddenly released into the air in large quantities and can be harmful even to healthy adults. In addition to the biological side effects of fireworks, the possible physical side effects of sudden sound and light phenomena (stress, hearing loss, fear in animals, confusion) and possible injuries caused by improper use must also be taken into account. In addition, the amount of money spent on a fireworks show at different events is a matter of constant debate. Therefore, before using fireworks to add colour to a celebration, it is worth considering the advantages, disadvantages and possible alternatives (music and light displays etc.)

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|  |  |  |  |
| --- | --- | --- | --- |
| combustible material | combustion promoters | substance responsible for the colour effect | air polluting combustion products |
| CFeS | O2$$NO\_{3}^{-}$$$$ClO\_{3}^{-}$$ | Li+K+ | SO2NO2 |

**Student sheet 13: Exploding colours**

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

Birthday? New Year's Eve? Olympics? Wedding? Whatever the occasion, fireworks are the highlight of the celebration. With the knowledge and technology of our time, we can create fireworks in countless different colours and shapes, but would you think that it would not exist without a 2,000-year-old coincidence? In ancient China, pieces of bamboo were burnt and exploded due to their hollow structure, believed to ward off evil spirits. This was the predecessor of fireworks. It took almost 1000 years for the first real fireworks with gunpowder to be invented, and almost another millennium for the Italians to colour the sky with lights. Here you will discover the background to these different colour phenomena.

The **most stable** energy state of an atom is called the **ground state**. In this state, the electrons of the atom are arranged in the lowest possible energy atomic orbitals. But when energy is applied (for example, when a substance is heated), **the electrons move to higher energy orbitals**, i.e. the atom enters an **excited state**. This state **is not stable**, so the atom will soon return to the ground state while **radiating the energy it has absorbed**. The energy difference between the ground state and the excited state is called the **excitation energy**.

MATERIALS AND EQUIPMENT: 1 mol/dm3 hydrochloric acid in beakers, solid NaCl in a screw cap (for plastic bottles), 1. unknown salt in a screw cap, 2. unknown salt in a screw cap, iron wire with cork stopper, alcohol/gas burner, matches

**Experiment I.:** Light the alcohol/gas burner. Immerse the end of the iron wire that you find on your tray in the hydrochloric acid (HCl solution) and then in the solid sodium chloride (NaCl). Hold the salt-coated end of the wire in the flame and observe the phenomenon.

**Observation:** The colour of the flame is ........................................................ due to the sodium chloride.

**Explanation:** The metal ion in the salt is atomized by heating, and its electrons are placed in an atomic orbital

with .................................... energy. When the ................................... state is broken, the atom radiated the

energy it had absorbed in the form of ................................... and got back into the ...............................................

The colours of fireworks are also caused by this process. What is the reason why fireworks can be every colour of the rainbow? The **excitation energy** is constant **for atoms of a given element**. This is why the **photons of the electromagnetic waves emitted have the same energy**. When the energy of these photons falls in the **visible light range (380-750 nm)**, we see **the colour of the flame that is characteristic of the atom**. Different metal salts are used to colour fireworks, in which metal ions are responsible for the flame colouring.

The colour of the flame depends on the wavelength of the electromagnetic radiation emitted (its symbol is **). The shorter the wavelength of the light, the closer the colour detected is to violet:

|  |  |
| --- | --- |
| **The colour of the flame** | **Wavelength, *λ* (nm)** |
| violet | 380 – 420 |
| blue | 420 – 490 |
| green | 490 – 575 |
| yellow | 575 – 585 |
| orange | 585 – 650 |
| red | 650 – 750 |

Different electromagnetic radiations differ not only in their wavelengths, but also in the energy of their photons. **The energy of a photon of radiation is inversely proportional to its wavelength**:

$$E\~\frac{1}{λ}$$

**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.**

**Experiment II.:** The tray contains two unknown salt compounds. Using the materials and tools available, how can you find out whether the excitation energy of the metal atoms in the two unknown metal salts is lower or higher than the excitation energy of the sodium in the kitchen salt?

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!

Amount of salt on the metal wire

Concentration of hydrochloric acid

Temperature of hydrochloric acid

Flame temperature

Time to keep it in the flame

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 II. a: …………………………………………………………………………………………………………………………………………………..

Experiment II. b: ………………………………………………………………………………………………………………………………………………….

9. Explanation:

Experiment II. a: The wavelength corresponding to the excitation energy of the metal atom of the unknown

metal salt 1 falls in the ....................... nm range.

Experiment II. b: The wavelength corresponding to the excitation energy of the metal atom of the unknown

metal salt 2 falls in the ....................... nm range.

10. CONCLUSION: The excitation energy of the metal atom of **unknown salt 1 / unknown salt 2** is less than the excitation energy of sodium, and the excitation energy of the metal atom of **unknown salt 1 / unknown salt 2** is greater.

11. LET'S THINK!

Although fireworks are an eye-catching sight, the different components and principles of operation make them much more dangerous than they first appear. When it explodes, it produces air pollutants (various gases and smoke, the latter including highly dangerous metals responsible for the colouring) which are suddenly released into the air in large quantities and can be harmful even to healthy adults. In addition to the biological side effects of fireworks, the possible physical side effects of sudden sound and light phenomena (stress, hearing loss, fear in animals, confusion) and possible injuries caused by improper use must also be taken into account. In addition, the amount of money spent on a fireworks show at different events is a matter of constant debate. Therefore, before using fireworks to add colour to a celebration, it is worth considering the advantages, disadvantages and possible alternatives (music and light displays etc.)

**Group the particles with the following symbols and formulae according to the role they play in the use of fireworks!** **C, SO2,Li+,** $NO\_{3}^{-}$**, Fe, O2,** $ClO\_{3}^{-}$**, NO2, S, K**+

|  |  |  |  |
| --- | --- | --- | --- |
| combustible material | combustion promoters | substance responsible for the colour effect | air polluting combustion products |
|  |  |  |  |

**Teacher notes for Student sheet 13: Exploding colours**

(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.

Birthday? New Year's Eve? Olympics? Wedding? Whatever the occasion, fireworks are the highlight of the celebration. With the knowledge and technology of our time, we can create fireworks in countless different colours and shapes, but would you think that it would not exist without a 2,000-year-old coincidence? In ancient China, pieces of bamboo were burnt and exploded due to their hollow structure, believed to ward off evil spirits. This was the predecessor of fireworks. It took almost 1000 years for the first real fireworks with gunpowder to be invented, and almost another millennium for the Italians to colour the sky with lights. Here you will discover the background to these different colour phenomena.

The **most stable** energy state of an atom is called the **ground state**. In this state, the electrons of the atom are arranged in the lowest possible energy atomic orbitals. But when energy is applied (for example, when a substance is heated), **the electrons move to higher energy orbitals**, i.e. the atom enters an **excited state**. This state **is not stable**, so the atom will soon return to the ground state while **radiating the energy it has absorbed**. The energy difference between the ground state and the excited state is called the **excitation energy**.

MATERIALS AND EQUIPMENT: 1 mol/dm3 hydrochloric acid in beakers, solid NaCl in a screw cap (for plastic bottles), 1. unknown salt in a screw cap, 2. unknown salt in a screw cap, iron wire with cork stopper, alcohol/gas burner, matches

**Experiment I.:** Light the alcohol/gas burner. Immerse the end of the iron wire that you find on your tray in the hydrochloric acid (HCl solution) and then in the solid sodium chloride (NaCl). Hold the salt-coated end of the wire in the flame and observe the phenomenon.

**Observation:** The colour of the flame is yellow due to the sodium chloride.

**Explanation:** The metal ion in the salt is atomized by heating, and its electrons are placed in an atomic orbital

with higher energy. When the excitation state is broken, the atom radiated the

energy it had absorbed in the form of yellow light and got back into the ground state.

The colours of fireworks are also caused by this process. What is the reason why fireworks can be every colour of the rainbow? The **excitation energy** is constant **for atoms of a given element**. This is why the **photons of the electromagnetic waves emitted have the same energy**. When the energy of these photons falls in the **visible light range (380-750 nm)**, we see **the colour of the flame that is characteristic of the atom**. Different metal salts are used to colour fireworks, in which metal ions are responsible for the flame colouring.

The colour of the flame depends on the wavelength of the electromagnetic radiation emitted (its symbol is **). The shorter the wavelength of the light, the closer the colour detected is to violet:

|  |  |
| --- | --- |
| **The colour of the flame** | **Wavelength, *λ* (nm)** |
| violet | 380 – 420 |
| blue | 420 – 490 |
| green | 490 – 575 |
| yellow | 575 – 585 |
| orange | 585 – 650 |
| red | 650 – 750 |

Different electromagnetic radiations differ not only in their wavelengths, but also in the energy of their photons. **The energy of a photon of radiation is inversely proportional to its wavelength**:

$$E\~\frac{1}{λ}$$

**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.**

**Experiment II.:** The tray contains two unknown salt compounds. Using the materials and tools available, how can you find out whether the excitation energy of the metal atoms in the two unknown metal salts is lower or higher than the excitation energy of the sodium in the kitchen salt?

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 metal salts.

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

The excitation energy and the colour of the flame and the wavelength of the light emitted.

3. HOW CAN YOU TEST THIS DEPENDENT VARIABLE?

By observing the colour of the flame test.

4. THIS IS THE ASSUMPTION (HYPOTHESIS):

If the metal salts changes (the independent variable changes as intended), then the excitation energy and thus the wavelength of the flame colour changes (the dependent variable will change in this way).

5. HOW CAN THE INDEPENDENT VARIABLE CHANGE?

|  |  |
| --- | --- |
| Experiment II.aWe repeat experiment I. with unknown metal salt 1. | Experiment II.bWe repeat experiment I. with unknown metal salt 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!

Amount of salt on the metal wire

Concentration of hydrochloric acid

Temperature of hydrochloric acid

[x]  Flame temperature

Time to keep it in the flame

7. THE STEPS OF THE EXPERIMENTS:

II. a: (1) We immerse the iron wire in the hydrochloric acid.

(2) We put the iron wire in the salt 1.

(3) We hold the iron wire in the flame.

II. b: (1) We immerse the iron wire in the hydrochloric acid.

(2) We put the iron wire in the salt 2.

(3) We hold the iron wire in the flame.

**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 II. a: The colour of the flame is brick red.

Experiment II. b: The colour of the flame is green.

9. Explanation:

Experiment II. a: The wavelength corresponding to the excitation energy of the metal atom of the unknown

metal salt 1 falls in the 650 – 750 nm range.

Experiment II. b: The wavelength corresponding to the excitation energy of the metal atom of the unknown

metal salt 2 falls in the 490 – 575 nm range.

10. CONCLUSION: The excitation energy of the metal atom of **unknown salt 1 / unknown salt 2** is less than the excitation energy of sodium, and the excitation energy of the metal atom of **unknown salt 1 / unknown salt 2** is greater.

11. LET'S THINK!

Although fireworks are an eye-catching sight, the different components and principles of operation make them much more dangerous than they first appear. When it explodes, it produces air pollutants (various gases and smoke, the latter including highly dangerous metals responsible for the colouring) which are suddenly released into the air in large quantities and can be harmful even to healthy adults. In addition to the biological side effects of fireworks, the possible physical side effects of sudden sound and light phenomena (stress, hearing loss, fear in animals, confusion) and possible injuries caused by improper use must also be taken into account. In addition, the amount of money spent on a fireworks show at different events is a matter of constant debate. Therefore, before using fireworks to add colour to a celebration, it is worth considering the advantages, disadvantages and possible alternatives (music and light displays etc.)

**Group the particles with the following symbols and formulae according to the role they play in the use of fireworks!** **C, SO2,Li+,** $NO\_{3}^{-}$**, Fe, O2,** $ClO\_{3}^{-}$**, NO2, S, K**+

|  |  |  |  |
| --- | --- | --- | --- |
| combustible material | combustion promoters | substance responsible for the colour effect | air polluting combustion products |
| CFeS | O2$$NO\_{3}^{-}$$$$ClO\_{3}^{-}$$ | Li+K+ | SO2NO2 |

END OF THE 13th STUDENT SHEETS AND TEACHER NOTES

**Student sheet 14: Can you walk on water?**

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

The common English name for the pond skater (using mirror translation) is the Jesus bug. It can walk on water and that's how it gets its prey. But how can it stay above the surface if its body is denser than the water? Because the interactions that hold the water molecules together (per unit surface area) are strong enough to hold the pond skater. Thus its legs, which have a large surface area relative to its body size, do not break the bonds between water molecules. The stronger the interactions between the particles of the liquid, the harder it is to separate them, so the surface area is harder to increase. What is the strongest interaction between water molecules called?

Underline or frame the correct answer or ~~cross out~~ the incorrect ones.

**Covalent bond / dispersion interaction / dipole-dipole interaction / hydrogen bond**

A water molecule inside a water droplet is surrounded on all sides by another water molecule, so the resultant force acting on it is zero. However, the water molecules on the surface are pulled into the liquid by the interaction with the other water molecules, because they can only interact with the air molecules in much weaker interactions. The interactions between particles of cooking oil are weaker than those between water molecules. They are therefore pulled together by a smaller force, and so the drops of cooking oil are smaller than those of water. The stronger the interactions between the molecules of the liquid, the **lower/higher** the surface tension of the liquid, and hence the **smaller/larger** the drops of liquid.

Among the water pollutants, substances with dual solubility, such as soaps, detergents and dishwashing liquids, containing both polar (ionic) and apolar components, are very dangerous for living organisms. They are called surfactants because they reduce the surface tension of water. This is because, at the interface between water and air, the polar part is in the water and the apolar part is in the air. They thus disrupt the strong interactions between water molecules. Therefore, the drops of soap solution are **smaller/larger** than water drops. In the following experiments, you will compare the surface tension of water and soap solution. **To do this, you need to measure the volume of a single drop of the two liquids.**

the surface layer of the soap solution (one molecule thick membrane)

MATERIALS AND EQUIPMENT: 2 Pasteur pipettes or small volume syringes (2 or 5 ml), 3 glasses, distilled water, soap solution

|  |  |
| --- | --- |
| Experiment 1:Count the number of drops that drip from 1 cm3 of distilled water and divide the 1 cm3 by the number of drops. | Experiment 2: Count the number of drops that drip from 1 cm3 of soap solution and divide the 1 cm3 by the number of drops. |
| number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Suck up 1 cm3 of water into the volumetric device.

(2) Count the number of drops that drop out of a given volume (Experiment 1).

(3) Repeat this with the soapy water (Experiment 2).

(4) For both liquids, record the number of drops that drop out, divide the total volume by the number of drops, and calculate the volume of a single drop. Compare the measured data.

**After the experiments are done, write down your observations. You can also draw the conclusion.**

Indicate the correct answer **by underlining or framing the bold words, or by ~~crossing out~~ the incorrect ones.**

1. OBSERVATIONS:

Experiment 1: There are ...... drops in 1 cm3 of water. So the volume of a single drop of water is ...... cm3.

Experiment 2: There are ...... drops of in 1 cm3 of soapy water. So the volume of a single drop of soap solution is

...... cm3.

2. Explanation: **Fewer/more** drops of the soap solution than of the water could be dripped from a given volume. That is, the volume of a drop of water is **smaller / bigger** than that of a drop of soap solution. This shows that the surface area of the soap solution has **less / more** force to hold the particles together than the surface area of the water.

3. CONCLUSION: The surface tension of the soap solution is **lower / higher** than that of the water.

4. LET’S THINK!

It is not only soap that acts as a surfactant, but also any substance that has both polar and apolar particles. This group includes, for example, alcohol and proteins. This is why egg whites can be made into a foam with a large surface area.

Between 2002 and 2007, the river Rába was repeatedly polluted with foam due to the release of surfactants used in leather tanning from three Austrian tanneries. This does not break down naturally, causing the river to foam up and harming wildlife. Once the manufacturing technology was changed, the foaming stopped.

In December 2020, the Rába foamed again, but experts checking the quality of water *"... did not detect any external source of pollution. The consistency (colour, smell, composition) of the foam did not indicate pollution with chemical origin. Given that the foaming was observed in the weir sub-water, it is assumed that it was caused by a small tidal surge due to the rainfall in recent days, which could have caused the foaming of pollen, dust and surfactants washed ashore.*"

1. From what natural source can surfactants be introduced into water? Mark with x!

[ ]  fertiliser [ ]  decomposing leaves [ ]  detergent [ ]  tractor fuel on the ground [ ]  manure

1. Could the pond skater run on the surface of surfactant-contaminated water? Give reasons for your answer!

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

1. What direct environmental damage can be caused by the presence of surfactants and the resulting foaming? Mark with x!

[ ]  Removing the layer of fat from the feathers of waterfowl. [ ]  Obstructing oxygen exchange in living water.

 [ ]  Reduction in the amount of light entering the living water. [ ]  Death of aquatic molluscs.

 [ ]  Nutrient uptake by aquatic plants.

**Teacher notes for Student sheet 14: Can you walk on 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.

The common English name for the pond skater (using mirror translation) is the Jesus bug. It can walk on water and that's how it gets its prey. But how can it stay above the surface if its body is denser than the water? Because the interactions that hold the water molecules together (per unit surface area) are strong enough to hold the pond skater. Thus its legs, which have a large surface area relative to its body size, do not break the bonds between water molecules. The stronger the interactions between the particles of the liquid, the harder it is to separate them, so the surface area is harder to increase. What is the strongest interaction between water molecules called?

Underline or frame the correct answer or ~~cross out~~ the incorrect ones.

**Covalent bond / dispersion interaction / dipole-dipole interaction / hydrogen bond**

A water molecule inside a water droplet is surrounded on all sides by another water molecule, so the resultant force acting on it is zero. However, the water molecules on the surface are pulled into the liquid by the interaction with the other water molecules, because they can only interact with the air molecules in much weaker interactions. The interactions between particles of cooking oil are weaker than those between water molecules. They are therefore pulled together by a smaller force, and so the drops of cooking oil are smaller than those of water. The stronger the interactions between the molecules of the liquid, the **lower/higher** the surface tension of the liquid, and hence the **smaller/larger** the drops of liquid.

Among the water pollutants, substances with dual solubility, such as soaps, detergents and dishwashing liquids, containing both polar (ionic) and apolar components, are very dangerous for living organisms. They are called surfactants because they reduce the surface tension of water. This is because, at the interface between water and air, the polar part is in the water and the apolar part is in the air. They thus disrupt the strong interactions between water molecules. Therefore, the drops of soap solution are **smaller/larger** than water drops. In the following experiments, you will compare the surface tension of water and soap solution. **To do this, you need to measure the volume of a single drop of the two liquids.**

the surface layer of the soap solution (one molecule thick membrane)

MATERIALS AND EQUIPMENT: 2 Pasteur pipettes or small volume syringes (2 or 5 ml), 3 glasses, distilled water, soap solution

|  |  |
| --- | --- |
| Experiment 1:Count the number of drops that drip from 1 cm3 of distilled water and divide the 1 cm3 by the number of drops. | Experiment 2: Count the number of drops that drip from 1 cm3 of soap solution and divide the 1 cm3 by the number of drops. |
| number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Suck up 1 cm3 of water into the volumetric device.

(2) Count the number of drops that drop out of a given volume (Experiment 1).

(3) Repeat this with the soapy water (Experiment 2).

(4) For both liquids, record the number of drops that drop out, divide the total volume by the number of drops, and calculate the volume of a single drop. Compare the measured data.

**After the experiments are done, write down your observations. You can also draw the conclusion.**

Indicate the correct answer **by underlining or framing the bold words, or by ~~crossing out~~ the incorrect ones.**

1. OBSERVATIONS:

Experiment 1: There are 19 drops in 1 cm3 of water. So the volume of a single drop of water is 0,053 cm3.

Experiment 2: There are 31 drops of in 1 cm3 of soapy water. So the volume of a single drop of soap solution is 0,032 cm3.

(Note: the number of droplets refers to a specific measurement under certain conditions and may vary significantly for different measuring devices and soap solution concentrations.)

2. Explanation: **Fewer/more** drops of the soap solution than of the water could be dripped from a given volume. That is, the volume of a drop of water is **smaller / bigger** than that of a drop of soap solution. This shows that the surface area of the soap solution has **less / more** force to hold the particles together than the surface area of the water.

3. CONCLUSION: The surface tension of the soap solution is **lower / higher** than that of the water.

4. LET’S THINK!

It is not only soap that acts as a surfactant, but also any substance that has both polar and apolar particles. This group includes, for example, alcohol and proteins. This is why egg whites can be made into a foam with a large surface area.

Between 2002 and 2007, the river Rába was repeatedly polluted with foam due to the release of surfactants used in leather tanning from three Austrian tanneries. This does not break down naturally, causing the river to foam up and harming wildlife. Once the manufacturing technology was changed, the foaming stopped.

In December 2020, the Rába foamed again, but experts checking the quality of water *"... did not detect any external source of pollution. The consistency (colour, smell, composition) of the foam did not indicate pollution with chemical origin. Given that the foaming was observed in the weir sub-water, it is assumed that it was caused by a small tidal surge due to the rainfall in recent days, which could have caused the foaming of pollen, dust and surfactants washed ashore.*"

1. From what natural source can surfactants be introduced into water? Mark with x!

[ ]  fertiliser [x]  decomposing leaves [ ]  detergent [ ]  tractor fuel on the ground [x]  manure

1. Could the pond skater run on the surface of surfactant-contaminated water? Give reasons for your answer!

No, because the force from the surface tension is not large enough to counterbalance the weight of the pond skater.

1. What direct environmental damage can be caused by the presence of surfactants and the resulting foaming? Mark with x!

[x]  Removing the layer of fat from the feathers of waterfowl. [ ]  Obstructing oxygen exchange in living water.

 [x]  Reduction in the amount of light entering the living water. [x]  Death of aquatic molluscs.

 [ ]  Nutrient uptake by aquatic plants.

**Student sheet 14: Can you walk on water?**

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

The common English name for the pond skater (using mirror translation) is the Jesus bug. It can walk on water and that's how it gets its prey. But how can it stay above the surface if its body is denser than the water? Because the interactions that hold the water molecules together (per unit surface area) are strong enough to hold the pond skater. Thus its legs, which have a large surface area relative to its body size, do not break the bonds between water molecules. The stronger the interactions between the particles of the liquid, the harder it is to separate them, so the surface area is harder to increase. What is the strongest interaction between water molecules called?

Underline or frame the correct answer or ~~cross out~~ the incorrect ones.

**Covalent bond / dispersion interaction / dipole-dipole interaction / hydrogen bond**

A water molecule inside a water droplet is surrounded on all sides by another water molecule, so the resultant force acting on it is zero. However, the water molecules on the surface are pulled into the liquid by the interaction with the other water molecules, because they can only interact with the air molecules in much weaker interactions. The interactions between particles of cooking oil are weaker than those between water molecules. They are therefore pulled together by a smaller force, and so the drops of cooking oil are smaller than those of water. The stronger the interactions between the molecules of the liquid, the **lower/higher** the surface tension of the liquid, and hence the **smaller/larger** the drops of liquid.

Among the water pollutants, substances with dual solubility, such as soaps, detergents and dishwashing liquids, containing both polar (ionic) and apolar components, are very dangerous for living organisms. They are called surfactants because they reduce the surface tension of water. This is because, at the interface between water and air, the polar part is in the water and the apolar part is in the air. They thus disrupt the strong interactions between water molecules. Therefore, the drops of soap solution are **smaller/larger** than water drops. In the following experiments, you will compare the surface tension of water and soap solution. **To do this, you need to measure the volume of a single drop of the two liquids.**

the surface layer of the soap solution (one molecule thick membrane)

MATERIALS AND EQUIPMENT: 2 Pasteur pipettes or small volume syringes (2 or 5 ml), 3 glasses, distilled water, soap solution

|  |  |
| --- | --- |
| Experiment 1:Count the number of drops that drip from 1 cm3 of distilled water and divide the 1 cm3 by the number of drops. | Experiment 2: Count the number of drops that drip from 1 cm3 of soap solution and divide the 1 cm3 by the number of drops. |
| number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Suck up 1 cm3 of water into the volumetric device.

(2) Count the number of drops that drop out of a given volume (Experiment 1).

(3) Repeat this with the soapy water (Experiment 2).

(4) For both liquids, record the number of drops that drop out, divide the total volume by the number of drops, and calculate the volume of a single drop. Compare the measured data.

**After the experiments are done, write down your observations. You can also draw the conclusion.**

Indicate the correct answer **by underlining or framing the bold words, or by ~~crossing out~~ the incorrect ones.**

1. OBSERVATIONS:

Experiment 1: There are ...... drops in 1 cm3 of water. So the volume of a single drop of water is ...... cm3.

Experiment 2: There are ...... drops of in 1 cm3 of soapy water. So the volume of a single drop of soap solution is

...... cm3.

2. Explanation: **Fewer/more** drops of the soap solution than of the water could be dripped from a given volume. That is, the volume of a drop of water is **smaller / bigger** than that of a drop of soap solution. This shows that the surface area of the soap solution has **less / more** force to hold the particles together than the surface area of the water.

3. CONCLUSION: The surface tension of the soap solution is **lower / higher** than that of the 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. 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 an **X** sign!

[ ]  The volume of the water samples. [ ]  The volume of the glass. [ ]  The temperature.

[ ]  The rate of dripping. [ ]  The density of the liquids.

[ ]  Diameter of the orifice of the volumetric device [ ]  Volume of the volumetric device.

9. LET’S THINK!

It is not only soap that acts as a surfactant, but also any substance that has both polar and apolar particles. This group includes, for example, alcohol and proteins. This is why egg whites can be made into a foam with a large surface area.

Between 2002 and 2007, the river Rába was repeatedly polluted with foam due to the release of surfactants used in leather tanning from three Austrian tanneries. This does not break down naturally, causing the river to foam up and harming wildlife. Once the manufacturing technology was changed, the foaming stopped.

In December 2020, the Rába foamed again, but experts checking the quality of water *"... did not detect any external source of pollution. The consistency (colour, smell, composition) of the foam did not indicate pollution with chemical origin. Given that the foaming was observed in the weir sub-water, it is assumed that it was caused by a small tidal surge due to the rainfall in recent days, which could have caused the foaming of pollen, dust and surfactants washed ashore.*"

1. From what natural source can surfactants be introduced into water? Mark with x!

[ ]  fertiliser [ ]  decomposing leaves [ ]  detergent [ ]  tractor fuel on the ground [ ]  manure

1. Could the pond skater run on the surface of surfactant-contaminated water? Give reasons for your answer!

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

1. What direct environmental damage can be caused by the presence of surfactants and the resulting foaming? Mark with x!

[ ]  Removing the layer of fat from the feathers of waterfowl. [ ]  Obstructing oxygen exchange in living water.

 [ ]  Reduction in the amount of light entering the living water. [ ]  Death of aquatic molluscs.

 [ ]  Nutrient uptake by aquatic plants.

**Teacher notes for Student sheet 14: Can you walk on 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.

The common English name for the pond skater (using mirror translation) is the Jesus bug. It can walk on water and that's how it gets its prey. But how can it stay above the surface if its body is denser than the water? Because the interactions that hold the water molecules together (per unit surface area) are strong enough to hold the pond skater. Thus its legs, which have a large surface area relative to its body size, do not break the bonds between water molecules. The stronger the interactions between the particles of the liquid, the harder it is to separate them, so the surface area is harder to increase. What is the strongest interaction between water molecules called?

Underline or frame the correct answer or ~~cross out~~ the incorrect ones.

**Covalent bond / dispersion interaction / dipole-dipole interaction / hydrogen bond**

A water molecule inside a water droplet is surrounded on all sides by another water molecule, so the resultant force acting on it is zero. However, the water molecules on the surface are pulled into the liquid by the interaction with the other water molecules, because they can only interact with the air molecules in much weaker interactions. The interactions between particles of cooking oil are weaker than those between water molecules. They are therefore pulled together by a smaller force, and so the drops of cooking oil are smaller than those of water. The stronger the interactions between the molecules of the liquid, the **lower/higher** the surface tension of the liquid, and hence the **smaller/larger** the drops of liquid.

Among the water pollutants, substances with dual solubility, such as soaps, detergents and dishwashing liquids, containing both polar (ionic) and apolar components, are very dangerous for living organisms. They are called surfactants because they reduce the surface tension of water. This is because, at the interface between water and air, the polar part is in the water and the apolar part is in the air. They thus disrupt the strong interactions between water molecules. Therefore, the drops of soap solution are **smaller/larger** than water drops. In the following experiments, you will compare the surface tension of water and soap solution. **To do this, you need to measure the volume of a single drop of the two liquids.**

the surface layer of the soap solution (one molecule thick membrane)

MATERIALS AND EQUIPMENT: 2 Pasteur pipettes or small volume syringes (2 or 5 ml), 3 glasses, distilled water, soap solution

|  |  |
| --- | --- |
| Experiment 1:Count the number of drops that drip from 1 cm3 of distilled water and divide the 1 cm3 by the number of drops. | Experiment 2: Count the number of drops that drip from 1 cm3 of soap solution and divide the 1 cm3 by the number of drops. |
| number of repetitions in class: | number of repetitions in class: |

STEPS OF THE EXPERIMENT

(1) Suck up 1 cm3 of water into the volumetric device.

(2) Count the number of drops that drop out of a given volume (Experiment 1).

(3) Repeat this with the soapy water (Experiment 2).

(4) For both liquids, record the number of drops that drop out, divide the total volume by the number of drops, and calculate the volume of a single drop. Compare the measured data.

**After the experiments are done, write down your observations. You can also draw the conclusion.**

Indicate the correct answer **by underlining or framing the bold words, or by ~~crossing out~~ the incorrect ones.**

1. OBSERVATIONS:

Experiment 1: There are 19 drops in 1 cm3 of water. So the volume of a single drop of water is 0,053 cm3.

Experiment 2: There are 31 drops of in 1 cm3 of soapy water. So the volume of a single drop of soap solution is 0,032 cm3.

(Note: the number of droplets refers to a specific measurement under certain conditions and may vary significantly for different measuring devices and soap solution concentrations.)

2. Explanation: **Fewer/more** drops of the soap solution than of the water could be dripped from a given volume. That is, the volume of a drop of water is **smaller / bigger** than that of a drop of soap solution. This shows that the surface area of the soap solution has **less / more** force to hold the particles together than the surface area of the water.

3. CONCLUSION: The surface tension of the soap solution is **lower / higher** than that of the 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. WHAT WAS THE INDEPENDENT VARIABLE THAT YOU HAD TO CHANGE IN THE EXPERIMENTS?

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

Whether or not there was soap dissolved in the water.

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

Surface tension of liquids.

6. HOW COULD YOU TEST THIS DEPENDENT VARIABLE?

By measuring the volume of liquid droplets.

7. THIS WAS THE ASSUMPTION (HYPOTHESIS):

If soap is dissolved in the water (the independent variable changes as intended), then it reduces the surface tension of the liquid (the dependent variable will change in this way).

8. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with an **X** sign!

[x]  The volume of the water samples. [ ]  The volume of the glass. [x]  The temperature.

[x]  The rate of dripping. [ ]  The density of the liquids.

[x]  Diameter of the orifice of the volumetric device [ ]  Volume of the volumetric device.

9. LET’S THINK!

It is not only soap that acts as a surfactant, but also any substance that has both polar and apolar particles. This group includes, for example, alcohol and proteins. This is why egg whites can be made into a foam with a large surface area.

Between 2002 and 2007, the river Rába was repeatedly polluted with foam due to the release of surfactants used in leather tanning from three Austrian tanneries. This does not break down naturally, causing the river to foam up and harming wildlife. Once the manufacturing technology was changed, the foaming stopped.

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1. From what natural source can surfactants be introduced into water? Mark with x!

[ ]  fertiliser [x]  decomposing leaves [ ]  detergent [ ]  tractor fuel on the ground [x]  manure

1. Could the pond skater run on the surface of surfactant-contaminated water? Give reasons for your answer!

No, because the force from the surface tension is not large enough to counterbalance the weight of the pond skater.

1. What direct environmental damage can be caused by the presence of surfactants and the resulting foaming? Mark with x!

[x]  Removing the layer of fat from the feathers of waterfowl. [ ]  Obstructing oxygen exchange in living water.

 [x]  Reduction in the amount of light entering the living water. [x]  Death of aquatic molluscs.

 [ ]  Nutrient uptake by aquatic plants.

**Student sheet 14: Can you walk on water?**

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

The common English name for the pond skater (using mirror translation) is the Jesus bug. It can walk on water and that's how it gets its prey. But how can it stay above the surface if its body is denser than the water? Because the interactions that hold the water molecules together (per unit surface area) are strong enough to hold the pond skater. Thus its legs, which have a large surface area relative to its body size, do not break the bonds between water molecules. The stronger the interactions between the particles of the liquid, the harder it is to separate them, so the surface area is harder to increase. What is the strongest interaction between water molecules called?

Underline or frame the correct answer or ~~cross out~~ the incorrect ones.

**Covalent bond / dispersion interaction / dipole-dipole interaction / hydrogen bond**

A water molecule inside a water droplet is surrounded on all sides by another water molecule, so the resultant force acting on it is zero. However, the water molecules on the surface are pulled into the liquid by the interaction with the other water molecules, because they can only interact with the air molecules in much weaker interactions. The interactions between particles of cooking oil are weaker than those between water molecules. They are therefore pulled together by a smaller force, and so the drops of cooking oil are smaller than those of water. The stronger the interactions between the molecules of the liquid, the **lower/higher** the surface tension of the liquid, and hence the **smaller/larger** the drops of liquid.

Among the water pollutants, substances with dual solubility, such as soaps, detergents and dishwashing liquids, containing both polar (ionic) and apolar components, are very dangerous for living organisms. They are called surfactants because they reduce the surface tension of water. This is because, at the interface between water and air, the polar part is in the water and the apolar part is in the air. They thus disrupt the strong interactions between water molecules. Therefore, the drops of soap solution are **smaller/larger** than water drops. In the following experiments, you will compare the surface tension of water and soap solution. **To do this, you need to measure the volume of a single drop of the two liquids.**

the surface layer of the soap solution (one molecule thick membrane)

MATERIALS AND EQUIPMENT: 2 Pasteur pipettes or small volume syringes (2 or 5 ml), 3 glasses, distilled water, soap solution

**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 how you can measure the volume of a drop of distilled water or a drop of soap solution.

|  |  |
| --- | --- |
| 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 an **X** sign!

[ ]  The volume of the water samples. [ ]  The volume of the glass. [ ]  The temperature.

[ ]  The rate of dripping. [ ]  The density of the liquids.

[ ]  Diameter of the orifice of the volumetric device [ ]  Volume of the volumetric device.

7. THE STEPS OF THE EXPERIMENTS:

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

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

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

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

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

**After the experiments are done, write down your observations. You can also draw the conclusion.**

Indicate the correct answer **by underlining or framing the bold words, or by ~~crossing out~~ the incorrect ones.**

8. OBSERVATIONS:

Experiment 1: There are ...... drops in 1 cm3 of water. So the volume of a single drop of water is ...... cm3.

Experiment 2: There are ...... drops of in 1 cm3 of soapy water. So the volume of a single drop of soap solution is

...... cm3.

9. Explanation: **Fewer/more** drops of the soap solution than of the water could be dripped from a given volume. That is, the volume of a drop of water is **smaller / bigger** than that of a drop of soap solution. This shows that the surface area of the soap solution has **less / more** force to hold the particles together than the surface area of the water.

10. CONCLUSION: The surface tension of the soap solution is **lower / higher** than that of the water.

11. LET’S THINK!

It is not only soap that acts as a surfactant, but also any substance that has both polar and apolar particles. This group includes, for example, alcohol and proteins. This is why egg whites can be made into a foam with a large surface area.

Between 2002 and 2007, the river Rába was repeatedly polluted with foam due to the release of surfactants used in leather tanning from three Austrian tanneries. This does not break down naturally, causing the river to foam up and harming wildlife. Once the manufacturing technology was changed, the foaming stopped.

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1. From what natural source can surfactants be introduced into water? Mark with x!

[ ]  fertiliser [ ]  decomposing leaves [ ]  detergent [ ]  tractor fuel on the ground [ ]  manure

1. Could the pond skater run on the surface of surfactant-contaminated water? Give reasons for your answer!

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

1. What direct environmental damage can be caused by the presence of surfactants and the resulting foaming? Mark with x!

[ ]  Removing the layer of fat from the feathers of waterfowl. [ ]  Obstructing oxygen exchange in living water.

 [ ]  Reduction in the amount of light entering the living water. [ ]  Death of aquatic molluscs.

 [ ]  Nutrient uptake by aquatic plants.

**Teacher notes for Student sheet 14: Can you walk on 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.

The common English name for the pond skater (using mirror translation) is the Jesus bug. It can walk on water and that's how it gets its prey. But how can it stay above the surface if its body is denser than the water? Because the interactions that hold the water molecules together (per unit surface area) are strong enough to hold the pond skater. Thus its legs, which have a large surface area relative to its body size, do not break the bonds between water molecules. The stronger the interactions between the particles of the liquid, the harder it is to separate them, so the surface area is harder to increase. What is the strongest interaction between water molecules called?

Underline or frame the correct answer or ~~cross out~~ the incorrect ones.

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A water molecule inside a water droplet is surrounded on all sides by another water molecule, so the resultant force acting on it is zero. However, the water molecules on the surface are pulled into the liquid by the interaction with the other water molecules, because they can only interact with the air molecules in much weaker interactions. The interactions between particles of cooking oil are weaker than those between water molecules. They are therefore pulled together by a smaller force, and so the drops of cooking oil are smaller than those of water. The stronger the interactions between the molecules of the liquid, the **lower/higher** the surface tension of the liquid, and hence the **smaller/larger** the drops of liquid.

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the surface layer of the soap solution (one molecule thick membrane)

MATERIALS AND EQUIPMENT: 2 Pasteur pipettes or small volume syringes (2 or 5 ml), 3 glasses, distilled water, soap solution

**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!**

Whether or not there is soap dissolved in the water.

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

Surface tension of liquids.

3. HOW CAN YOU TEST THIS DEPENDENT VARIABLE?

By measuring the volume of liquid droplets.

4. THIS IS THE ASSUMPTION (HYPOTHESIS):

If soap is dissolved in the water (the independent variable changes as intended), then it reduces the surface tension of the liquid (the dependent variable will change in this way).

5. HOW CAN THE INDEPENDENT VARIABLE CHANGE? Plan how you can measure the volume of a drop of distilled water or a drop of soap solution.

|  |  |
| --- | --- |
| Experiment 1:We count the number of drops that drip from 1 cm3 of distilled water and divide the 1 cm3 by the number of drops. | Experiment 2: We count the number of drops that drip from 1 cm3 of soap solution and divide the 1 cm3 by the number of drops. |
| 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 an **X** sign!

[x]  The volume of the water samples. [ ]  The volume of the glass. [x]  The temperature.

[x]  The rate of dripping. [ ]  The density of the liquids.

[x]  Diameter of the orifice of the volumetric device [ ]  Volume of the volumetric device.

7. THE STEPS OF THE EXPERIMENTS:

(1) We suck up 1 cm3 of water into the volumetric device.

(2) We count the number of drops that drop out of a given volume (Experiment 1).

(3) We repeat this with the soapy water (Experiment 2).

(4) For both liquids, we record the number of drops that drop out, divide the total volume by the number of drops, and calculate the volume of a single drop. We compare the measured data.

**After the experiments are done, write down your observations. You can also draw the conclusion.**

Indicate the correct answer **by underlining or framing the bold words, or by ~~crossing out~~ the incorrect ones.**

8. OBSERVATIONS:

Experiment 1: There are 19 drops in 1 cm3 of water. So the volume of a single drop of water is 0,053 cm3.

Experiment 2: There are 31 drops of in 1 cm3 of soapy water. So the volume of a single drop of soap solution is 0,032 cm3.

(Note: the number of droplets refers to a specific measurement under certain conditions and may vary significantly for different measuring devices and soap solution concentrations.)

9. Explanation: **Fewer/more** drops of the soap solution than of the water could be dripped from a given volume. That is, the volume of a drop of water is **smaller / bigger** than that of a drop of soap solution. This shows that the surface area of the soap solution has **less / more** force to hold the particles together than the surface area of the water.

10. CONCLUSION: The surface tension of the soap solution is **lower / higher** than that of the water.

11. LET’S THINK!

It is not only soap that acts as a surfactant, but also any substance that has both polar and apolar particles. This group includes, for example, alcohol and proteins. This is why egg whites can be made into a foam with a large surface area.

Between 2002 and 2007, the river Rába was repeatedly polluted with foam due to the release of surfactants used in leather tanning from three Austrian tanneries. This does not break down naturally, causing the river to foam up and harming wildlife. Once the manufacturing technology was changed, the foaming stopped.

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1. From what natural source can surfactants be introduced into water? Mark with x!

[ ]  fertiliser [x]  decomposing leaves [ ]  detergent [ ]  tractor fuel on the ground [x]  manure

1. Could the pond skater run on the surface of surfactant-contaminated water? Give reasons for your answer!

No, because the force from the surface tension is not large enough to counterbalance the weight of the pond skater.

1. What direct environmental damage can be caused by the presence of surfactants and the resulting foaming? Mark with x!

[x]  Removing the layer of fat from the feathers of waterfowl. [ ]  Obstructing oxygen exchange in living water.

 [x]  Reduction in the amount of light entering the living water. [x]  Death of aquatic molluscs.

 [ ]  Nutrient uptake by aquatic plants.

END OF THE 14th STUDENT SHEETS AND TEACHER NOTES

**Student sheet** **15: The superglue and others**

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

You want the superglue to set really fast, but you never want the natural gas used in the gas cooker to explode, right? So we must always control the speed of the chemical processes according to our needs. First, chemists have to find out what substances need to react with each other for a particular purpose. For example, the substance in superglue, cyanoacrylate, which reacts rapidly, almost instantaneously, with water in the air, was discovered by Harry Coover in 1942. However, the speed of reactions is influenced by factors other than the quality of the reactants. Many tragedies have occurred when the concentration of natural gas in the air of a flat exceeded the lower explosive limit due to inattention, and a burning cigarette or a spark from a light switch caused the gas mixture to explode at high temperatures. We will therefore now investigate how the concentration of reactants and temperature affect the rate of chemical reactions.

MATERIALS AND EQUIPMENT: hot and cold water baths, liquids in Pasteur pipettes/dropper flasks: 1 dropper of 0.5 mol/dm3 sodium thiosulphate solution (Na2S2O3 solution), 1 dropper of 1.0 mol/dm3 hydrochloric acid (HCl solution), 1 dropper of water, 1 diagram printed on A4 paper in a plastic bag, 1 mobile phone with stopwatch function

First, we need a medium-speed reaction, which we will learn about in the next experiment.

**Experiment I:** Place the droppers containing the Na2S2O3 solution and the hydrochloric acid solution in the cold water bath with the closed ends down (or place the bottles containing these solutions in the cold water bath). When they have cooled, drop 1 drop of Na2S2O3 solution in the centre of the circle marked "Experiment I" on the plastic folder and drop 1 drop of hydrochloric acid (HCl solution) on it. Using the stopwatch function on your mobile phone, measure the time that elapses before you can no longer see the dot in the middle of the circle under the liquid. Record your experience and explain the changes!

**Observation:** After a while, the solution first became .............................., and later changed to ..............................

The dot in the middle of the circle is no longer visible after this time: ....................................................

**Explanation:** The reaction between the sodium thiosulphate solution and hydrochloric acid is given by the

following equation **which has to be balanced**. The colour was caused by the resulting ........................... The

pungent smelling gas is the ................................................

Na2S2O3 + …. HCl → …. NaCl + SO2 + S + H2O

**Experiment II:** In the circles labelled "II. a)” and “II. b)" on the plastic folder, carry out the following experiments.

|  |  |
| --- | --- |
| II. a): 1 drop of **cold** Na2S2O3 solution + 1 drop of **cold** water + 1 drop of **cold** hydrochloric acid | II. b): 1 drop of **warm** Na2S2O3 solution + 1 drop of **warm** hydrochloric acid |

STEPS OF THE EXPERIMENT

II. a):

(1) Place the dropper or bottle containing the water in the cold water bath.

(2) Drop 1 drop of cold Na2S2O3 solution into the circle marked II.a).

(3) Drop 1 drop of cold water on it.

(4) Drop 1 drop of cold hydrochloric acid on it.

(5) Measure the time that must elapse before you can no longer see the dot in the middle of the circle.

II. b):

(1) Place the droppers or bottles containing the Na2S2O3 solution and the hydrochloric acid into the warm water bath.

(2) Drop 1 drop of warm Na2S2O3 solution into the circle marked II.b).

(3) Drop 1 drop of warm hydrochloric acid on it.

(4) Measure the time that must elapse before you can no longer see the dot in the middle of the circle.

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

1. OBSERVATION:

II. a) ……………………………………………………………………………………………………………………………………………………………………

II. b) ……………………………………………………………………………………………………………………………………………………………………

2. Explanation:

II. a) ……………………………………………………………………………………………………………………………………………………………………

II. b) ……………………………………………………………………………………………………………………………………………………………………

3. CONCLUSION:

II. a) ……………………………………………………………………………………………………………………………………………………………………

II. b) ……………………………………………………………………………………………………………………………………………………………………

4. LET’S THINK!

Suppose a friend fell while cycling and you disinfected a nasty bruise on his skin with Betadine. But in all the effort, some of the brown Betadine solution spilled on your friend's favourite light-coloured shorts. The iodine in Betadine is not water-soluble, but the internet says that "*Betadine solution ...can be removed with a solution of sodium thiosulphate (fixative salt)*". Solid sodium thiosulphate can be bought cheaply from chemists. The chemical reaction equation is as follows: 2 Na2S2O3 + I2 → Na2S4O6 + 2 NaI. The resulting products are colourless and water-soluble, so they are removed by the next wash. Which sodium thiosulphate solution of the solid salt should you make if you want the brown stain to disappear from the shorts as quickly as possible? Underline the correct answer!

A) Dilute and cold solution. B) Dilute and warm solution. C) Concentrated and cold solution. D) Concentrated and warm solution.

**Teacher notes for Student sheet 15: The superglue and others**

(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.

You want the superglue to set really fast, but you never want the natural gas used in the gas cooker to explode, right? So we must always control the speed of the chemical processes according to our needs. First, chemists have to find out what substances need to react with each other for a particular purpose. For example, the substance in superglue, cyanoacrylate, which reacts rapidly, almost instantaneously, with water in the air, was discovered by Harry Coover in 1942. However, the speed of reactions is influenced by factors other than the quality of the reactants. Many tragedies have occurred when the concentration of natural gas in the air of a flat exceeded the lower explosive limit due to inattention, and a burning cigarette or a spark from a light switch caused the gas mixture to explode at high temperatures. We will therefore now investigate how the concentration of reactants and temperature affect the rate of chemical reactions.

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First, we need a medium-speed reaction, which we will learn about in the next experiment.

**Experiment I:** Place the droppers containing the Na2S2O3 solution and the hydrochloric acid solution in the cold water bath with the closed ends down (or place the bottles containing these solutions in the cold water bath). When they have cooled, drop 1 drop of Na2S2O3 solution in the centre of the circle marked "Experiment I" on the plastic folder and drop 1 drop of hydrochloric acid (HCl solution) on it. Using the stopwatch function on your mobile phone, measure the time that elapses before you can no longer see the dot in the middle of the circle under the liquid. Record your experience and explain the changes!

**Observation:** After a while, the solution first became white (opalescent), and later changed to yellow.

The dot in the middle of the circle is no longer visible after this time: 30 s.

**Explanation:** The reaction between the sodium thiosulphate solution and hydrochloric acid is given by the

following equation **which has to be balanced**. The colour was caused by the resulting sulfur. The

pungent smelling gas is the sulfur dioxide.

Na2S2O3 + 2 HCl → 2 NaCl + SO2 + S + H2O

**Experiment II:** In the circles labelled "II. a)” and “II. b)" on the plastic folder, carry out the following experiments.

|  |  |
| --- | --- |
| II. a): 1 drop of **cold** Na2S2O3 solution + 1 drop of **cold** water + 1 drop of **cold** hydrochloric acid | II. b): 1 drop of **warm** Na2S2O3 solution + 1 drop of **warm** hydrochloric acid |

STEPS OF THE EXPERIMENT

II. a):

(1) Place the dropper or bottle containing the water in the cold water bath.

(2) Drop 1 drop of cold Na2S2O3 solution into the circle marked II.a).

(3) Drop 1 drop of cold water on it.

(4) Drop 1 drop of cold hydrochloric acid on it.

(5) Measure the time that must elapse before you can no longer see the dot in the middle of the circle.

II. b):

(1) Place the droppers or bottles containing the Na2S2O3 solution and the hydrochloric acid into the warm water bath.

(2) Drop 1 drop of warm Na2S2O3 solution into the circle marked II.b).

(3) Drop 1 drop of warm hydrochloric acid on it.

(4) Measure the time that must elapse before you can no longer see the dot in the middle of the circle.

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

1. OBSERVATION:

II. a) In the case of dilution with water, the point in the centre of the circle is not visible after about 60 s.

II. b) For warm solutions, the dot in the middle of the circle is not visible after about 10 s.

2. Explanation:

II. a) At lower concentrations, there are fewer particles in a given space, so the particles collide less often and the reaction takes place more slowly.

II. b) At higher temperatures, more particles have the energy to meet the activation energy requirement of the process. The particles move faster and collide more often. So there are more frequent useful collisions.

3. CONCLUSION:

II. a) By reducing the concentration, the reaction rate can be reduced.

II. b) By increasing the temperature, the reaction rate can be increased.

4. LET’S THINK!

Suppose a friend fell while cycling and you disinfected a nasty bruise on his skin with Betadine. But in all the effort, some of the brown Betadine solution spilled on your friend's favourite light-coloured shorts. The iodine in Betadine is not water-soluble, but the internet says that "*Betadine solution ...can be removed with a solution of sodium thiosulphate (fixative salt)*". Solid sodium thiosulphate can be bought cheaply from chemists. The chemical reaction equation is as follows: 2 Na2S2O3 + I2 → Na2S4O6 + 2 NaI. The resulting products are colourless and water-soluble, so they are removed by the next wash. Which sodium thiosulphate solution of the solid salt should you make if you want the brown stain to disappear from the shorts as quickly as possible? Underline the correct answer!

A) Dilute and cold solution. B) Dilute and warm solution. C) Concentrated and cold solution. D) Concentrated and warm solution.

**Student sheet 15: The superglue and others**

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

You want the superglue to set really fast, but you never want the natural gas used in the gas cooker to explode, right? So we must always control the speed of the chemical processes according to our needs. First, chemists have to find out what substances need to react with each other for a particular purpose. For example, the substance in superglue, cyanoacrylate, which reacts rapidly, almost instantaneously, with water in the air, was discovered by Harry Coover in 1942. However, the speed of reactions is influenced by factors other than the quality of the reactants. Many tragedies have occurred when the concentration of natural gas in the air of a flat exceeded the lower explosive limit due to inattention, and a burning cigarette or a spark from a light switch caused the gas mixture to explode at high temperatures. We will therefore now investigate how the concentration of reactants and temperature affect the rate of chemical reactions.

MATERIALS AND EQUIPMENT: hot and cold water baths, liquids in Pasteur pipettes/dropper flasks: 1 dropper of 0.5 mol/dm3 sodium thiosulphate solution (Na2S2O3 solution), 1 dropper of 1.0 mol/dm3 hydrochloric acid (HCl solution), 1 dropper of water, 1 diagram printed on A4 paper in a plastic bag, 1 mobile phone with stopwatch function

First, we need a medium-speed reaction, which we will learn about in the next experiment.

**Experiment I:** Place the droppers containing the Na2S2O3 solution and the hydrochloric acid solution in the cold water bath with the closed ends down (or place the bottles containing these solutions in the cold water bath). When they have cooled, drop 1 drop of Na2S2O3 solution in the centre of the circle marked "Experiment I" on the plastic folder and drop 1 drop of hydrochloric acid (HCl solution) on it. Using the stopwatch function on your mobile phone, measure the time that elapses before you can no longer see the dot in the middle of the circle under the liquid. Record your experience and explain the changes!

**Observation:** After a while, the solution first became .............................., and later changed to ..............................

The dot in the middle of the circle is no longer visible after this time: ....................................................

**Explanation:** The reaction between the sodium thiosulphate solution and hydrochloric acid is given by the

following equation **which has to be balanced**. The colour was caused by the resulting ........................... The

pungent smelling gas is the ................................................

Na2S2O3 + …. HCl → …. NaCl + SO2 + S + H2O

**Experiment II:** In the circles labelled "II. a)” and “II. b)" on the plastic folder, carry out the following experiments.

|  |  |
| --- | --- |
| II. a): 1 drop of **cold** Na2S2O3 solution + 1 drop of **cold** water + 1 drop of **cold** hydrochloric acid | II. b): 1 drop of **warm** Na2S2O3 solution + 1 drop of **warm** hydrochloric acid |

STEPS OF THE EXPERIMENT

II. a):

(1) Place the dropper or bottle containing the water in the cold water bath.

(2) Drop 1 drop of cold Na2S2O3 solution into the circle marked II.a).

(3) Drop 1 drop of cold water on it.

(4) Drop 1 drop of cold hydrochloric acid on it.

(5) Measure the time that must elapse before you can no longer see the dot in the middle of the circle.

II. b):

(1) Place the droppers or bottles containing the Na2S2O3 solution and the hydrochloric acid into the warm water bath.

(2) Drop 1 drop of warm Na2S2O3 solution into the circle marked II.b).

(3) Drop 1 drop of warm hydrochloric acid on it.

(4) Measure the time that must elapse before you can no longer see the dot in the middle of the circle.

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

1. OBSERVATION:

II. a) ……………………………………………………………………………………………………………………………………………………………………

II. b) ……………………………………………………………………………………………………………………………………………………………………

2. Explanation:

II. a) ……………………………………………………………………………………………………………………………………………………………………

II. b) ……………………………………………………………………………………………………………………………………………………………………

3. CONCLUSION:

II. a) ……………………………………………………………………………………………………………………………………………………………………

II. b) ……………………………………………………………………………………………………………………………………………………………………

**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 WERE THE INDEPENDENT VARIABLES THAT YOU HAD TO CHANGE IN THE EXPERIMENTS?

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

a) ………………………………………………………… b) …………………………………………………………

5. WHAT WAS THE DEPENDENT VARIABLE?

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

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

7. THESE WERE THE ASSUMPTIONS (HYPOTHESISES):

II.a) If ………………………………………………………………………………………………………………………………………. (the independent

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

II.b) 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!

II. a) [ ]  Volume of solutions. [ ]  Concentration of solutions.

 [ ]  Temperature of the solutions. [ ]  The order in which the solutions are dropped.

II. b) [ ]  Volume of solutions. [ ]  Concentration of solutions.

 [ ]  Temperature of the solutions. [ ]  The order in which the solutions are dropped.

9. LET’S THINK!

Suppose a friend fell while cycling and you disinfected a nasty bruise on his skin with Betadine. But in all the effort, some of the brown Betadine solution spilled on your friend's favourite light-coloured shorts. The iodine in Betadine is not water-soluble, but the internet says that "*Betadine solution ...can be removed with a solution of sodium thiosulphate (fixative salt)*". Solid sodium thiosulphate can be bought cheaply from chemists. The chemical reaction equation is as follows: 2 Na2S2O3 + I2 → Na2S4O6 + 2 NaI. The resulting products are colourless and water-soluble, so they are removed by the next wash. Which sodium thiosulphate solution of the solid salt should you make if you want the brown stain to disappear from the shorts as quickly as possible? Underline the correct answer!

A) Dilute and cold solution. B) Dilute and warm solution. C) Concentrated and cold solution. D) Concentrated and warm solution.

**Teacher notes for Student sheet 15: The superglue and others**

(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.

You want the superglue to set really fast, but you never want the natural gas used in the gas cooker to explode, right? So we must always control the speed of the chemical processes according to our needs. First, chemists have to find out what substances need to react with each other for a particular purpose. For example, the substance in superglue, cyanoacrylate, which reacts rapidly, almost instantaneously, with water in the air, was discovered by Harry Coover in 1942. However, the speed of reactions is influenced by factors other than the quality of the reactants. Many tragedies have occurred when the concentration of natural gas in the air of a flat exceeded the lower explosive limit due to inattention, and a burning cigarette or a spark from a light switch caused the gas mixture to explode at high temperatures. We will therefore now investigate how the concentration of reactants and temperature affect the rate of chemical reactions.

MATERIALS AND EQUIPMENT: hot and cold water baths, liquids in Pasteur pipettes/dropper flasks: 1 dropper of 0.5 mol/dm3 sodium thiosulphate solution (Na2S2O3 solution), 1 dropper of 1.0 mol/dm3 hydrochloric acid (HCl solution), 1 dropper of water, 1 diagram printed on A4 paper in a plastic bag, 1 mobile phone with stopwatch function

First, we need a medium-speed reaction, which we will learn about in the next experiment.

**Experiment I:** Place the droppers containing the Na2S2O3 solution and the hydrochloric acid solution in the cold water bath with the closed ends down (or place the bottles containing these solutions in the cold water bath). When they have cooled, drop 1 drop of Na2S2O3 solution in the centre of the circle marked "Experiment I" on the plastic folder and drop 1 drop of hydrochloric acid (HCl solution) on it. Using the stopwatch function on your mobile phone, measure the time that elapses before you can no longer see the dot in the middle of the circle under the liquid. Record your experience and explain the changes!

**Observation:** After a while, the solution first became white (opalescent), and later changed to yellow.

The dot in the middle of the circle is no longer visible after this time: 30 s.

**Explanation:** The reaction between the sodium thiosulphate solution and hydrochloric acid is given by the

following equation **which has to be balanced**. The colour was caused by the resulting sulfur. The

pungent smelling gas is the sulfur dioxide.

Na2S2O3 + 2 HCl → 2 NaCl + SO2 + S + H2O

**Experiment II:** In the circles labelled "II. a)” and “II. b)" on the plastic folder, carry out the following experiments.

|  |  |
| --- | --- |
| II. a): 1 drop of **cold** Na2S2O3 solution + 1 drop of **cold** water + 1 drop of **cold** hydrochloric acid | II. b): 1 drop of **warm** Na2S2O3 solution + 1 drop of **warm** hydrochloric acid |

STEPS OF THE EXPERIMENT

II. a):

(1) Place the dropper or bottle containing the water in the cold water bath.

(2) Drop 1 drop of cold Na2S2O3 solution into the circle marked II.a).

(3) Drop 1 drop of cold water on it.

(4) Drop 1 drop of cold hydrochloric acid on it.

(5) Measure the time that must elapse before you can no longer see the dot in the middle of the circle.

II. b):

(1) Place the droppers or bottles containing the Na2S2O3 solution and the hydrochloric acid into the warm water bath.

(2) Drop 1 drop of warm Na2S2O3 solution into the circle marked II.b).

(3) Drop 1 drop of warm hydrochloric acid on it.

(4) Measure the time that must elapse before you can no longer see the dot in the middle of the circle.

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

1. OBSERVATION:

II. a) In the case of dilution with water, the point in the centre of the circle is not visible after about 60 s.

II. b) For warm solutions, the dot in the middle of the circle is not visible after about 10 s.

2. Explanation:

II. a) At lower concentrations, there are fewer particles in a given space, so the particles collide less often and the reaction takes place more slowly.

II. b) At higher temperatures, more particles have the energy to meet the activation energy requirement of the process. The particles move faster and collide more often. So there are more frequent useful collisions.

3. CONCLUSION:

II. a) By reducing the concentration, the reaction rate can be reduced.

II. b) By increasing the temperature, the reaction rate can be increased.

**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 WERE THE INDEPENDENT VARIABLES THAT YOU HAD TO CHANGE IN THE EXPERIMENTS?

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

a) Concentration. b) Temperature.

5. WHAT WAS THE DEPENDENT VARIABLE? The reaction time.

6. HOW COULD YOU TEST THIS DEPENDENT VARIABLE?

By losing the visibility of the point in the centre of the circle.

7. THESE WERE THE ASSUMPTION (HYPOTHESISES):

II.a) If we reduce the concentration (the independent variable changes as intended), then it increases the time needed for the reaction to take place (the dependent variable will change in this way).

II.b) If the temperature is raised (the independent variable changes as intended), then it reduces the time needed for the reaction to take place (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!

II. a) [ ]  Volume of solutions. [ ]  Concentration of solutions.

 [x]  Temperature of the solutions. [ ]  The order in which the solutions are dropped.

II. b) [x]  Volume of solutions. [x]  Concentration of solutions.

 [ ]  Temperature of the solutions. [ ]  The order in which the solutions are dropped.

9. LET’S THINK!

Suppose a friend fell while cycling and you disinfected a nasty bruise on his skin with Betadine. But in all the effort, some of the brown Betadine solution spilled on your friend's favourite light-coloured shorts. The iodine in Betadine is not water-soluble, but the internet says that "*Betadine solution ...can be removed with a solution of sodium thiosulphate (fixative salt)*". Solid sodium thiosulphate can be bought cheaply from chemists. The chemical reaction equation is as follows: 2 Na2S2O3 + I2 → Na2S4O6 + 2 NaI. The resulting products are colourless and water-soluble, so they are removed by the next wash. Which sodium thiosulphate solution of the solid salt should you make if you want the brown stain to disappear from the shorts as quickly as possible? Underline the correct answer!

A) Dilute and cold solution. B) Dilute and warm solution. C) Concentrated and cold solution. D) Concentrated and warm solution.

**Student sheet 15: The superglue and others**

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

You want the superglue to set really fast, but you never want the natural gas used in the gas cooker to explode, right? So we must always control the speed of the chemical processes according to our needs. First, chemists have to find out what substances need to react with each other for a particular purpose. For example, the substance in superglue, cyanoacrylate, which reacts rapidly, almost instantaneously, with water in the air, was discovered by Harry Coover in 1942. However, the speed of reactions is influenced by factors other than the quality of the reactants. Many tragedies have occurred when the concentration of natural gas in the air of a flat exceeded the lower explosive limit due to inattention, and a burning cigarette or a spark from a light switch caused the gas mixture to explode at high temperatures. We will therefore now investigate how the concentration of reactants and temperature affect the rate of chemical reactions.

MATERIALS AND EQUIPMENT: hot and cold water baths, liquids in Pasteur pipettes/dropper flasks: 1 dropper of 0.5 mol/dm3 sodium thiosulphate solution (Na2S2O3 solution), 1 dropper of 1.0 mol/dm3 hydrochloric acid (HCl solution), 1 dropper of water, 1 diagram printed on A4 paper in a plastic bag, 1 mobile phone with stopwatch function

First, we need a medium-speed reaction, which we will learn about in the next experiment.

**Experiment I:** Place the droppers containing the Na2S2O3 solution and the hydrochloric acid solution in the cold water bath with the closed ends down (or place the bottles containing these solutions in the cold water bath). When they have cooled, drop 1 drop of Na2S2O3 solution in the centre of the circle marked "Experiment I" on the plastic folder and drop 1 drop of hydrochloric acid (HCl solution) on it. Using the stopwatch function on your mobile phone, measure the time that elapses before you can no longer see the dot in the middle of the circle under the liquid. Record your experience and explain the changes!

**Observation:** After a while, the solution first became .............................., and later changed to ..............................

The dot in the middle of the circle is no longer visible after this time: ....................................................

**Explanation:** The reaction between the sodium thiosulphate solution and hydrochloric acid is given by the

following equation **which has to be balanced**. The colour was caused by the resulting ........................... The

pungent smelling gas is the ................................................

Na2S2O3 + …. HCl → …. NaCl + SO2 + S + H2O

**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.**

**Experiment II:** Use Experiment I as a control experiment, and compare the observations of the following two experiments to its observations. How could you use the materials and equipment you have to

(a) **slow down** the reaction in Experiment I in the circle marked II.a)?

(b) **accelerate** the reaction in Experiment I in the circle marked II.b)?

1. WHAT ARE THE INDEPENDENT VARIABLES THAT YOU HAVE TO CHANGE IN THE EXPERIMENTS?

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

a) ………………………………………………………… b) …………………………………………………………

2. WHAT IS THE DEPENDENT VARIABLE?

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

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

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

4. THESE ARE THE ASSUMPTIONS (HYPOTHESISES):

II.a) If ………………………………………………………………………………………………………………………………………. (the independent

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

II.b) If ………………………………………………………………………………………………………………………………………. (the independent

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

5. HOW CAN THE INDEPENDENT VARIABLES CHANGE? Plan which liquids and in which order should be dropped into the circles drawn on the sheet in the plastic bag and marked as follows.

|  |  |
| --- | --- |
| II. a):  | II. b):  |
| 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 an **X** sign!

II. a) [ ]  Volume of solutions. [ ]  Concentration of solutions.

 [ ]  Temperature of the solutions. [ ]  The order in which the solutions are dropped.

II. b) [ ]  Volume of solutions. [ ]  Concentration of solutions.

 [ ]  Temperature of the solutions. [ ]  The order in which the solutions are dropped.

7. THE STEPS OF THE EXPERIMENTS:

II. a):

(1) Place the dropper or bottle containing the ………………….……………………. in the ……………………….water bath.

(2) Drop …………………………………………………………………………………………………………….. into the circle marked II.a).

(3) Drop …………………………………………………………………………………..…..………… on it.

(4) Drop …………………………………………………………………………………..……………… on it.

(5) Measure …………………………………………………………………………………………………………………………………………………...

II. b):

(1) Place the droppers or bottles containing the ……………………………………………………………………………………………

……………………………………………………………………………………………... into the ………………………………………….. water bath.

(2) Drop …………………………………………………………………………………………………………….. into the circle marked II.b).

(3) Drop …………………………………………………………………………………..……………… on it.

(4) Measure …………………………………………………………………………………………………………………………………………………...

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

8. OBSERVATION:

II. a) ……………………………………………………………………………………………………………………………………………………………………

II. b) ……………………………………………………………………………………………………………………………………………………………………

9. Explanation:

II. a) ……………………………………………………………………………………………………………………………………………………………………

II. b) ……………………………………………………………………………………………………………………………………………………………………

10. CONCLUSION:

II. a) ……………………………………………………………………………………………………………………………………………………………………

II. b) ……………………………………………………………………………………………………………………………………………………………………

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A) Dilute and cold solution. B) Dilute and warm solution. C) Concentrated and cold solution. D) Concentrated and warm solution.

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

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**Experiment I:** Place the droppers containing the Na2S2O3 solution and the hydrochloric acid solution in the cold water bath with the closed ends down (or place the bottles containing these solutions in the cold water bath). When they have cooled, drop 1 drop of Na2S2O3 solution in the centre of the circle marked "Experiment I" on the plastic folder and drop 1 drop of hydrochloric acid (HCl solution) on it. Using the stopwatch function on your mobile phone, measure the time that elapses before you can no longer see the dot in the middle of the circle under the liquid. Record your experience and explain the changes!

**Observation:** After a while, the solution first became white (opalescent), and later changed to yellow.

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(b) **accelerate** the reaction in Experiment I in the circle marked II.b)?

1. WHAT ARE THE INDEPENDENT VARIABLES THAT YOU HAVE TO CHANGE IN THE EXPERIMENTS?

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

a) Concentration. b) Temperature.

2. WHAT IS THE DEPENDENT VARIABLE?

The reaction time.

3. HOW CAN YOU TEST THIS DEPENDENT VARIABLE?

By losing the visibility of the point in the centre of the circle.

4. THESE ARE THE ASSUMPTIONS (HYPOTHESISES):

II.a) If we reduce the concentration (the independent variable changes as intended), then it increases the time needed for the reaction to take place (the dependent variable will change in this way).

II.b) If the temperature is raised (the independent variable changes as intended), then it reduces the time needed for the reaction to take place (the dependent variable will change in this way).

5. HOW CAN THE INDEPENDENT VARIABLES CHANGE? Plan which liquids and in which order should be dropped into the circles drawn on the sheet in the plastic bag and marked as follows.

|  |  |
| --- | --- |
| II. a): 1 drop of **cold** Na2S2O3 solution + 1 drop of **cold** water + 1 drop of **cold** hydrochloric acid | II. b): 1 drop of **warm** Na2S2O3 solution + 1 drop of **warm** hydrochloric acid |
| 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 an **X** sign!

II. a) [ ]  Volume of solutions. [ ]  Concentration of solutions.

 [x]  Temperature of the solutions. [ ]  The order in which the solutions are dropped.

II. b) [x]  Volume of solutions. [x]  Concentration of solutions.

 [ ]  Temperature of the solutions. [ ]  The order in which the solutions are dropped.

7. THE STEPS OF THE EXPERIMENTS:

II. a):

(1) Place the dropper or bottle containing the water in the cold water bath.

(2) Drop 1 drop of cold Na2S2O3 solution into the circle marked II.a).

(3) Drop 1 drop of cold water on it.

(4) Drop 1 drop of cold hydrochloric acid on it.

(5) Measure the time that must elapse before you can no longer see the dot in the middle of the circle.

II. b):

(1) Place the droppers or bottles containing the Na2S2O3 solution and the hydrochloric acid into the warm water bath.

(2) Drop 1 drop of warm Na2S2O3 solution into the circle marked II.b).

(3) Drop 1 drop of warm hydrochloric acid on it.

(4) Measure the time that must elapse before you can no longer see the dot in the middle of the circle.

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

8. OBSERVATION:

II. a) In the case of dilution with water, the point in the centre of the circle is not visible after about 60 s.

II. b) For warm solutions, the dot in the middle of the circle is not visible after about 10 s.

9. Explanation:

II. a) At lower concentrations, there are fewer particles in a given space, so the particles collide less often and the reaction takes place more slowly.

II. b) At higher temperatures, more particles have the energy to meet the activation energy requirement of the process. The particles move faster and collide more often. So there are more frequent useful collisions.

10. CONCLUSION:

II. a) By reducing the concentration, the reaction rate can be reduced.

II. b) By increasing the temperature, the reaction rate can be increased.

11. LET’S THINK!

Suppose a friend fell while cycling and you disinfected a nasty bruise on his skin with Betadine. But in all the effort, some of the brown Betadine solution spilled on your friend's favourite light-coloured shorts. The iodine in Betadine is not water-soluble, but the internet says that "*Betadine solution ...can be removed with a solution of sodium thiosulphate (fixative salt)*". Solid sodium thiosulphate can be bought cheaply from chemists. The chemical reaction equation is as follows: 2 Na2S2O3 + I2 → Na2S4O6 + 2 NaI. The resulting products are colourless and water-soluble, so they are removed by the next wash. Which sodium thiosulphate solution of the solid salt should you make if you want the brown stain to disappear from the shorts as quickly as possible? Underline the correct answer!

A) Dilute and cold solution. B) Dilute and warm solution. C) Concentrated and cold solution. D) Concentrated and warm solution.

END OF THE 15th STUDENT SHEETS AND TEACHER NOTES

**Student sheet** **16: Geyser in a bottle – the Mentos-Cola story**

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

Years ago, a rumour circulated on the internet that a combination of Diet Coke and Mentos candy had allegedly caused the death of a Brazilian boy. It was reported that the reaction between the ingredients in Diet Coke and Mentos resulted in the formation of a dangerous compound that produced a powerful gas release. We will now investigate whether there is any truth to this report.

Carbon dioxide gas is added to the solution during the production of carbonated soft drinks. In a closed bottle, carbon dioxide is involved in the physical and chemical processes that lead to equilibrium between the gas space and the liquid, and inside the liquid, as described by the equations below.

Indicate the nature and location of the process by underlining or framing the correct words/terms.

**A) CO2(g) ⇌ CO2(aq)** It is a **physical/chemical** process that takes place between the **gas phase and the liquid phase/in the liquid phase**.

**B) CO2(aq) + H2O(f) ⇌ H2CO3(aq)**It is a **physical/chemical** process that takes place between the **gas phase and the liquid phase/in the liquid phase**.

How do the processes marked A) and B) change when the bottle is opened? Indicate the direction of change and justify your choice.

**A) CO2(g) ⇌ CO2(aq)** This equilibrium is shifted to the **left/right** because ……………………………………………………………..

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

**B) CO2(aq) + H2O(f) ⇌ H2CO3(aq)**This equilibrium is shifted to the **left/right** because ……………………………………………

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

**Experiment I:** Observe the following demonstration experiment.[[1]](#footnote-1) Write down your observations!

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

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

Use your phone's camera to examine the surface of the Mentos candy you got at maximum magnification! What do you find?

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

**Experiment II:**

MATERIALS AND EQUIPMENT: three 100 cm3 beakers or similar sized glass or plastic containers, tweezers, a piece of glass, a piece of terracotta (e.g. from a flower pot or a piece of brick), a piece of cloth, a smartphone or magnifying glass, carbonated mineral water or soda water.

|  |  |  |
| --- | --- | --- |
| Experiment 1carbonated mineral water | Experiment 2carbonated mineral water + a piece of glass | Experiment 2carbonated mineral water + a piece of terracotta |

THE STEPS OF THE EXPERIMENTS:

(1) Examine the surface of the piece of glass and the piece of terracotta with your phone's camera at the highest magnification possible.

(2) Carefully pour about the same volume of sparkling mineral water into the three glass jars.

(3) Use the carbonated mineral water in the first jar as a control.

(4) Using tweezers, place the piece of glass in the second container.

(5) Using tweezers, place the piece of terracotta in the third container.

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

1. OBSERVATIONS:

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

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

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

2. Explanation: Surface roughness of solids increases the specific surface area of the solid. The pores of solids with a high specific surface area contain gas particles that act as a bubble nucleus in a solution supersaturated with carbon dioxide. The glass surface is **more even/ more uneven** and has a **smaller/higher** specific surface area than the terracotta, hence the rate of gas evolution on its surface is **lower/higher** than on the terracotta. Using the same volume and temperature of mineral water, the mineral water in the **first/second/third** beaker of the open systems in the experiment bubbles up carbon dioxide gas most rapidly.

3. CONCLUSION: The specific surface area of the Mentos candy passing through the digestive tract to the stomach **decreases/increases** due to the digestive juices, resembling more **a piece of glass/ a piece of terracotta**. Therefore, a **more violent/less violent** reaction takes place between the cola and the candy in the stomach than in the cola bottle. Our digestive tract is a **closed/open** system, so the gas produced in our stomach **can/can't escape** through the body orifices. The incident in this article **may/may not** have happened.

4. LET'S THINK!

"*Almost every brewer has come across a beer that behaves like a geyser, whether it's a home brew or a store-bought. Overflowing beer is a bad sign in itself, but in extreme bad cases the beer bottle can explode, although fortunately this is very rare. Opinions differ on how much pressure a beer bottle can withstand without exploding, as this varies from manufacturer to manufacturer. For most disposable beer bottles the tolerance is 2-4 bar, for reusable beer bottles it is 3-7 bar, and for champagne bottles it can be even higher."*

While carbon dioxide is added to soft drinks during production, in the beer and champagne mentioned in the quote above, carbon dioxide is produced as a by-product of fermentation. Complete the equation for the reaction of alcoholic fermentation with glucose. The formula for ethyl alcohol is C2H5OH.

C6H12O6 = …………………………………………………………………

Sealed beer/champagne bottles and cans are closed systems. Depending on the conditions of storage and transport, the ratio of dissolved to undissolved carbon dioxide may vary, so the pressure inside the bottle will also vary. Circle the arrows in the text that explain the increase in pressure in the bottle.

solubility of carbon dioxide ↑↓

the amount of gaseous carbon dioxide in the bottle ↑↓

temperature ↑↓

the pressure in the bottle ↑↓

**Teacher notes for Student sheet 16: Geyser in a bottle – the Mentos-Cola story**

(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.

Years ago, a rumour circulated on the internet that a combination of Diet Coke and Mentos candy had allegedly caused the death of a Brazilian boy. It was reported that the reaction between the ingredients in Diet Coke and Mentos resulted in the formation of a dangerous compound that produced a powerful gas release. We will now investigate whether there is any truth to this report.

Carbon dioxide gas is added to the solution during the production of carbonated soft drinks. In a closed bottle, carbon dioxide is involved in the physical and chemical processes that lead to equilibrium between the gas space and the liquid, and inside the liquid, as described by the equations below.

Indicate the nature and location of the process by underlining or framing the correct words/terms.

**A) CO2(g) ⇌ CO2(aq)** It is a **physical/chemical** process that takes place between the **gas phase and the liquid phase/in the liquid phase**.

**B) CO2(aq) + H2O(f) ⇌ H2CO3(aq)**It is a **physical/chemical** process that takes place between the **gas phase and the liquid phase/in the liquid phase**.

How do the processes marked A) and B) change when the bottle is opened? Indicate the direction of change and justify your choice.

**A) CO2(g) ⇌ CO2(aq)** This equilibrium is shifted to the **left/right** because when the bottle is opened, the pressure and concentration of carbon dioxide above the liquid phase decreases, so the equilibrium is shifted towards the formation of gaseous carbon dioxide.

**B) CO2(aq) + H2O(f) ⇌ H2CO3(aq)**This equilibrium is shifted to the **left/right** because due to the shift in the process indicated by A), the concentration of dissolved carbon dioxide decreases, leading to the decomposition of carbonic acid molecules.

**Experiment I:** Observe the following demonstration experiment.[[2]](#footnote-2) Write down your observations!

The Mentos candy has a strong foaming effect. About half of the cola has "come out" of the bottle.

Use your phone's camera to examine the surface of the Mentos candy you got at maximum magnification! What do you find?

The surface of the candy is not smooth and has crater-like indentations and bulges, which increase the specific surface area of the candy.

**Experiment II:**

MATERIALS AND EQUIPMENT: three 100 cm3 beakers or similar sized glass or plastic containers, tweezers, a piece of glass, a piece of terracotta (e.g. from a flower pot or a piece of brick), a piece of cloth, a smartphone or magnifying glass, carbonated mineral water or soda water.

|  |  |  |
| --- | --- | --- |
| Experiment 1carbonated mineral water | Experiment 2carbonated mineral water + a piece of glass | Experiment 2carbonated mineral water + a piece of terracotta |

THE STEPS OF THE EXPERIMENTS:

(1) Examine the surface of the piece of glass and the piece of terracotta with your phone's camera at the highest magnification possible.

(2) Carefully pour about the same volume of sparkling mineral water into the three glass jars.

(3) Use the carbonated mineral water in the first jar as a control.

(4) Using tweezers, place the piece of glass in the second container.

(5) Using tweezers, place the piece of terracotta in the third container.

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

1. OBSERVATIONS:

Experiment 1: Gas bubbles adhere to the walls of the glass vessel, one of which occasionally rises above the liquid.

Experiment 2: Gas bubbles adhere to the surface of the glass, and gas evolution is slightly more intense than in the first experiment.

Experiment 3: A lot of gas bubbles adhere to the surface of the piece of terracotta, and a lively effervescence can be observed in the environment of the solid material.

2. Explanation: Surface roughness of solids increases the specific surface area of the solid. The pores of solids with a high specific surface area contain gas particles that act as a bubble nucleus in a solution supersaturated with carbon dioxide. The glass surface is **more even/ more uneven** and has a **smaller/higher** specific surface area than the terracotta, hence the rate of gas evolution on its surface is **lower/higher** than on the terracotta. Using the same volume and temperature of mineral water, the mineral water in the **first/second/third** beaker of the open systems in the experiment bubbles up carbon dioxide gas most rapidly.

3. CONCLUSION: The specific surface area of the Mentos candy passing through the digestive tract to the stomach **decreases/increases** due to the digestive juices, resembling more **a piece of glass/ a piece of terracotta**. Therefore, a **more violent/less violent** reaction takes place between the cola and the candy in the stomach than in the cola bottle. Our digestive tract is a **closed/open** system, so the gas produced in our stomach **can/can't escape** through the body orifices. The incident in this article **may/may not** have happened.

4. LET'S THINK!

"*Almost every brewer has come across a beer that behaves like a geyser, whether it's a home brew or a store-bought. Overflowing beer is a bad sign in itself, but in extreme bad cases the beer bottle can explode, although fortunately this is very rare. Opinions differ on how much pressure a beer bottle can withstand without exploding, as this varies from manufacturer to manufacturer. For most disposable beer bottles the tolerance is 2-4 bar, for reusable beer bottles it is 3-7 bar, and for champagne bottles it can be even higher."*

While carbon dioxide is added to soft drinks during production, in the beer and champagne mentioned in the quote above, carbon dioxide is produced as a by-product of fermentation. Complete the equation for the reaction of alcoholic fermentation with glucose. The formula for ethyl alcohol is C2H5OH.

C6H12O6 = **2 C2H5OH + 2 CO2**

Sealed beer/champagne bottles and cans are closed systems. Depending on the conditions of storage and transport, the ratio of dissolved to undissolved carbon dioxide may vary, so the pressure inside the bottle will also vary. Circle the arrows in the text that explain the increase in pressure in the bottle.

solubility of carbon dioxide ↑↓

the amount of gaseous carbon dioxide in the bottle ↑↓

temperature ↑↓

the pressure in the bottle ↑↓

**Student sheet 16: Geyser in a bottle – the Mentos-Cola story**

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

Years ago, a rumour circulated on the internet that a combination of Diet Coke and Mentos candy had allegedly caused the death of a Brazilian boy. It was reported that the reaction between the ingredients in Diet Coke and Mentos resulted in the formation of a dangerous compound that produced a powerful gas release. We will now investigate whether there is any truth to this report.

Carbon dioxide gas is added to the solution during the production of carbonated soft drinks. In a closed bottle, carbon dioxide is involved in the physical and chemical processes that lead to equilibrium between the gas space and the liquid, and inside the liquid, as described by the equations below.

Indicate the nature and location of the process by underlining or framing the correct words/terms.

**A) CO2(g) ⇌ CO2(aq)** It is a **physical/chemical** process that takes place between the **gas phase and the liquid phase/in the liquid phase**.

**B) CO2(aq) + H2O(f) ⇌ H2CO3(aq)**It is a **physical/chemical** process that takes place between the **gas phase and the liquid phase/in the liquid phase**.

How do the processes marked A) and B) change when the bottle is opened? Indicate the direction of change and justify your choice.

**A) CO2(g) ⇌ CO2(aq)** This equilibrium is shifted to the **left/right** because ……………………………………………………………..

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

**B) CO2(aq) + H2O(f) ⇌ H2CO3(aq)**This equilibrium is shifted to the **left/right** because ……………………………………………

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

**Experiment I:** Observe the following demonstration experiment.[[3]](#footnote-3) Write down your observations!

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

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Use your phone's camera to examine the surface of the Mentos candy you got at maximum magnification! What do you find?

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

**Experiment II:**

MATERIALS AND EQUIPMENT: three 100 cm3 beakers or similar sized glass or plastic containers, tweezers, a piece of glass, a piece of terracotta (e.g. from a flower pot or a piece of brick), a piece of cloth, a smartphone or magnifying glass, carbonated mineral water or soda water.

|  |  |  |
| --- | --- | --- |
| Experiment 1carbonated mineral water | Experiment 2carbonated mineral water + a piece of glass | Experiment 2carbonated mineral water + a piece of terracotta |

THE STEPS OF THE EXPERIMENTS:

(1) Examine the surface of the piece of glass and the piece of terracotta with your phone's camera at the highest magnification possible.

(2) Carefully pour about the same volume of sparkling mineral water into the three glass jars.

(3) Use the carbonated mineral water in the first jar as a control.

(4) Using tweezers, place the piece of glass in the second container.

(5) Using tweezers, place the piece of terracotta in the third container.

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

1. OBSERVATIONS:

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

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

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

2. Explanation: Surface roughness of solids increases the specific surface area of the solid. The pores of solids with a high specific surface area contain gas particles that act as a bubble nucleus in a solution supersaturated with carbon dioxide. The glass surface is **more even/ more uneven** and has a **smaller/higher** specific surface area than the terracotta, hence the rate of gas evolution on its surface is **lower/higher** than on the terracotta. Using the same volume and temperature of mineral water, the mineral water in the **first/second/third** beaker of the open systems in the experiment bubbles up carbon dioxide gas most rapidly.

3. CONCLUSION: The specific surface area of the Mentos candy passing through the digestive tract to the stomach **decreases/increases** due to the digestive juices, resembling more **a piece of glass/ a piece of terracotta**. Therefore, a **more violent/less violent** reaction takes place between the cola and the candy in the stomach than in the cola bottle. Our digestive tract is a **closed/open** system, so the gas produced in our stomach **can/can't escape** through the body orifices. The incident in this article **may/may not** have happened.

**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? ……………………………………………………………………………………….

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7. THIS WAS THE ASSUMPTION (HYPOTHESIS):……………………………………………………………………………………………………..

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

8. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with an **X** sign!

[ ]  The shape of the glass vessel. [ ]  The carbon dioxide content of the mineral water.

[ ]  The volume of the mineral water. [ ]  The temperature of the mineral water.

9. LET'S THINK!

"*Almost every brewer has come across a beer that behaves like a geyser, whether it's a home brew or a store-bought. Overflowing beer is a bad sign in itself, but in extreme bad cases the beer bottle can explode, although fortunately this is very rare. Opinions differ on how much pressure a beer bottle can withstand without exploding, as this varies from manufacturer to manufacturer. For most disposable beer bottles the tolerance is 2-4 bar, for reusable beer bottles it is 3-7 bar, and for champagne bottles it can be even higher."*

While carbon dioxide is added to soft drinks during production, in the beer and champagne mentioned in the quote above, carbon dioxide is produced as a by-product of fermentation. Complete the equation for the reaction of alcoholic fermentation with glucose. The formula for ethyl alcohol is C2H5OH.

C6H12O6 = …………………………………………………………………

Sealed beer/champagne bottles and cans are closed systems. Depending on the conditions of storage and transport, the ratio of dissolved to undissolved carbon dioxide may vary, so the pressure inside the bottle will also vary. Circle the arrows in the text that explain the increase in pressure in the bottle.

solubility of carbon dioxide ↑↓

the amount of gaseous carbon dioxide in the bottle ↑↓

temperature ↑↓

the pressure in the bottle ↑↓

**Teacher notes for Student sheet 16: Geyser in a bottle – the Mentos-Cola story**

(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.

Years ago, a rumour circulated on the internet that a combination of Diet Coke and Mentos candy had allegedly caused the death of a Brazilian boy. It was reported that the reaction between the ingredients in Diet Coke and Mentos resulted in the formation of a dangerous compound that produced a powerful gas release. We will now investigate whether there is any truth to this report.

Carbon dioxide gas is added to the solution during the production of carbonated soft drinks. In a closed bottle, carbon dioxide is involved in the physical and chemical processes that lead to equilibrium between the gas space and the liquid, and inside the liquid, as described by the equations below.

Indicate the nature and location of the process by underlining or framing the correct words/terms.

**A) CO2(g) ⇌ CO2(aq)** It is a **physical/chemical** process that takes place between the **gas phase and the liquid phase/in the liquid phase**.

**B) CO2(aq) + H2O(f) ⇌ H2CO3(aq)**It is a **physical/chemical** process that takes place between the **gas phase and the liquid phase/in the liquid phase**.

How do the processes marked A) and B) change when the bottle is opened? Indicate the direction of change and justify your choice.

**A) CO2(g) ⇌ CO2(aq)** This equilibrium is shifted to the **left/right** because when the bottle is opened, the pressure and concentration of carbon dioxide above the liquid phase decreases, so the equilibrium is shifted towards the formation of gaseous carbon dioxide.

**B) CO2(aq) + H2O(f) ⇌ H2CO3(aq)**This equilibrium is shifted to the **left/right** because due to the shift in the process indicated by A), the concentration of dissolved carbon dioxide decreases, leading to the decomposition of carbonic acid molecules.

**Experiment I:** Observe the following demonstration experiment.[[4]](#footnote-4) Write down your observations!

The Mentos candy has a strong foaming effect. About half of the cola has "come out" of the bottle.

Use your phone's camera to examine the surface of the Mentos candy you got at maximum magnification! What do you find?

The surface of the candy is not smooth and has crater-like indentations and bulges, which increase the specific surface area of the candy.

**Experiment II:**

MATERIALS AND EQUIPMENT: three 100 cm3 beakers or similar sized glass or plastic containers, tweezers, a piece of glass, a piece of terracotta (e.g. from a flower pot or a piece of brick), a piece of cloth, a smartphone or magnifying glass, carbonated mineral water or soda water.

|  |  |  |
| --- | --- | --- |
| Experiment 1carbonated mineral water | Experiment 2carbonated mineral water + a piece of glass | Experiment 2carbonated mineral water + a piece of terracotta |

THE STEPS OF THE EXPERIMENTS:

(1) Examine the surface of the piece of glass and the piece of terracotta with your phone's camera at the highest magnification possible.

(2) Carefully pour about the same volume of sparkling mineral water into the three glass jars.

(3) Use the carbonated mineral water in the first jar as a control.

(4) Using tweezers, place the piece of glass in the second container.

(5) Using tweezers, place the piece of terracotta in the third container.

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

1. OBSERVATIONS:

Experiment 1: Gas bubbles adhere to the walls of the glass vessel, one of which occasionally rises above the liquid.

Experiment 2: Gas bubbles adhere to the surface of the glass, and gas evolution is slightly more intense than in the first experiment.

Experiment 3: A lot of gas bubbles adhere to the surface of the piece of terracotta, and a lively effervescence can be observed in the environment of the solid material.

2. Explanation: Surface roughness of solids increases the specific surface area of the solid. The pores of solids with a high specific surface area contain gas particles that act as a bubble nucleus in a solution supersaturated with carbon dioxide. The glass surface is **more even/ more uneven** and has a **smaller/higher** specific surface area than the terracotta, hence the rate of gas evolution on its surface is **lower/higher** than on the terracotta. Using the same volume and temperature of mineral water, the mineral water in the **first/second/third** beaker of the open systems in the experiment bubbles up carbon dioxide gas most rapidly.

3. CONCLUSION: The specific surface area of the Mentos candy passing through the digestive tract to the stomach **decreases/increases** due to the digestive juices, resembling more **a piece of glass/ a piece of terracotta**. Therefore, a **more violent/less violent** reaction takes place between the cola and the candy in the stomach than in the cola bottle. Our digestive tract is a **closed/open** system, so the gas produced in our stomach **can/can't escape** through the body orifices. The incident in this article **may/may not** have happened.

**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!**

Quality/specific surface area of solids placed in carbonated mineral water.

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

The intensity of gas evolution.

6. HOW COULD YOU TEST THIS DEPENDENT VARIABLE?

We have observed the rate of gas evolution and the amount of gas bubbles that form in the liquid.

7. THIS WAS THE ASSUMPTION (HYPOTHESIS): The more uneven the surface of the solid placed in the mineral water, i.e. the higher the specific surface area, the more intense the formation of gas bubbles will be.

8. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with an **X** sign!

[ ]  The shape of the glass vessel. [x]  The carbon dioxide content of the mineral water.

[ ]  The volume of the mineral water. [x]  The temperature of the mineral water.

9. LET'S THINK!

"*Almost every brewer has come across a beer that behaves like a geyser, whether it's a home brew or a store-bought. Overflowing beer is a bad sign in itself, but in extreme bad cases the beer bottle can explode, although fortunately this is very rare. Opinions differ on how much pressure a beer bottle can withstand without exploding, as this varies from manufacturer to manufacturer. For most disposable beer bottles the tolerance is 2-4 bar, for reusable beer bottles it is 3-7 bar, and for champagne bottles it can be even higher."*

While carbon dioxide is added to soft drinks during production, in the beer and champagne mentioned in the quote above, carbon dioxide is produced as a by-product of fermentation. Complete the equation for the reaction of alcoholic fermentation with glucose. The formula for ethyl alcohol is C2H5OH.

C6H12O6 = **2 C2H5OH + 2 CO2**

Sealed beer/champagne bottles and cans are closed systems. Depending on the conditions of storage and transport, the ratio of dissolved to undissolved carbon dioxide may vary, so the pressure inside the bottle will also vary. Circle the arrows in the text that explain the increase in pressure in the bottle.

solubility of carbon dioxide ↑↓

the amount of gaseous carbon dioxide in the bottle ↑↓

temperature ↑↓

the pressure in the bottle ↑↓

**Student sheet 16: Geyser in a bottle – the Mentos-Cola story**

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

Years ago, a rumour circulated on the internet that a combination of Diet Coke and Mentos candy had allegedly caused the death of a Brazilian boy. It was reported that the reaction between the ingredients in Diet Coke and Mentos resulted in the formation of a dangerous compound that produced a powerful gas release. We will now investigate whether there is any truth to this report.

Carbon dioxide gas is added to the solution during the production of carbonated soft drinks. In a closed bottle, carbon dioxide is involved in the physical and chemical processes that lead to equilibrium between the gas space and the liquid, and inside the liquid, as described by the equations below.

Indicate the nature and location of the process by underlining or framing the correct words/terms.

**A) CO2(g) ⇌ CO2(aq)** It is a **physical/chemical** process that takes place between the **gas phase and the liquid phase/in the liquid phase**.

**B) CO2(aq) + H2O(f) ⇌ H2CO3(aq)**It is a **physical/chemical** process that takes place between the **gas phase and the liquid phase/in the liquid phase**.

How do the processes marked A) and B) change when the bottle is opened? Indicate the direction of change and justify your choice.

**A) CO2(g) ⇌ CO2(aq)** This equilibrium is shifted to the **left/right** because ……………………………………………………………..

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

**B) CO2(aq) + H2O(f) ⇌ H2CO3(aq)**This equilibrium is shifted to the **left/right** because ……………………………………………

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

**Experiment I:** Observe the following demonstration experiment.[[5]](#footnote-5) Write down your observations!

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

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

Use your phone's camera to examine the surface of the Mentos candy you got at maximum magnification! What do you find?

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

**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.**

**Experiment II:** Design experiments to find out what can cause gas to evolve in a carbonated liquid! Model (substitute) Coke and Mentos with the available substances!

MATERIALS AND EQUIPMENT: three 100 cm3 beakers or similar sized glass or plastic containers, tweezers, a piece of glass, a piece of terracotta (e.g. from a flower pot or a piece of brick), a piece of cloth, a smartphone or magnifying glass, carbonated mineral water or soda water.

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):…………………………………………………………………………………………………………..

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

|  |  |  |
| --- | --- | --- |
| Experiment 1 | Experiment 2 | Experiment 3 |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

5. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with an **X** sign!

[ ]  The shape of the glass vessel. [ ]  The carbon dioxide content of the mineral water.

[ ]  The volume of the mineral water. [ ]  The temperature of the mineral water.

6. 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, and by underlining or framing the correct words or ~~crossing out~~ the incorrect ones.

7. OBSERVATION:

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

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

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

8. Explanation: Surface roughness of solids increases the specific surface area of the solid. The pores of solids with a high specific surface area contain gas particles that act as a bubble nucleus in a solution supersaturated with carbon dioxide. The glass surface is **more even/ more uneven** and has a **smaller/higher** specific surface area than the terracotta, hence the rate of gas evolution on its surface is **lower/higher** than on the terracotta. Using the same volume and temperature of mineral water, the mineral water in the **first/second/third** beaker of the open systems in the experiment bubbles up carbon dioxide gas most rapidly.

CONCLUSION: The specific surface area of the Mentos candy passing through the digestive tract to the stomach **decreases/increases** due to the digestive juices, resembling more **a piece of glass/ a piece of terracotta**. Therefore, a **more violent/less violent** reaction takes place between the cola and the candy in the stomach than in the cola bottle. Our digestive tract is a **closed/open** system, so the gas produced in our stomach **can/can't escape** through the body orifices. The incident in this article **may/may not** have happened.

9. LET'S THINK!

"*Almost every brewer has come across a beer that behaves like a geyser, whether it's a home brew or a store-bought. Overflowing beer is a bad sign in itself, but in extreme bad cases the beer bottle can explode, although fortunately this is very rare. Opinions differ on how much pressure a beer bottle can withstand without exploding, as this varies from manufacturer to manufacturer. For most disposable beer bottles the tolerance is 2-4 bar, for reusable beer bottles it is 3-7 bar, and for champagne bottles it can be even higher."*

While carbon dioxide is added to soft drinks during production, in the beer and champagne mentioned in the quote above, carbon dioxide is produced as a by-product of fermentation. Complete the equation for the reaction of alcoholic fermentation with glucose. The formula for ethyl alcohol is C2H5OH.

C6H12O6 = …………………………………………………………………

Sealed beer/champagne bottles and cans are closed systems. Depending on the conditions of storage and transport, the ratio of dissolved to undissolved carbon dioxide may vary, so the pressure inside the bottle will also vary. Circle the arrows in the text that explain the increase in pressure in the bottle.

solubility of carbon dioxide ↑↓

the amount of gaseous carbon dioxide in the bottle ↑↓

temperature ↑↓

the pressure in the bottle ↑↓

**Teacher notes for Student sheet 16: Geyser in a bottle – the Mentos-Cola story**

(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.

Years ago, a rumour circulated on the internet that a combination of Diet Coke and Mentos candy had allegedly caused the death of a Brazilian boy. It was reported that the reaction between the ingredients in Diet Coke and Mentos resulted in the formation of a dangerous compound that produced a powerful gas release. We will now investigate whether there is any truth to this report.

Carbon dioxide gas is added to the solution during the production of carbonated soft drinks. In a closed bottle, carbon dioxide is involved in the physical and chemical processes that lead to equilibrium between the gas space and the liquid, and inside the liquid, as described by the equations below.

Indicate the nature and location of the process by underlining or framing the correct words/terms.

**A) CO2(g) ⇌ CO2(aq)** It is a **physical/chemical** process that takes place between the **gas phase and the liquid phase/in the liquid phase**.

**B) CO2(aq) + H2O(f) ⇌ H2CO3(aq)**It is a **physical/chemical** process that takes place between the **gas phase and the liquid phase/in the liquid phase**.

How do the processes marked A) and B) change when the bottle is opened? Indicate the direction of change and justify your choice.

**A) CO2(g) ⇌ CO2(aq)** This equilibrium is shifted to the **left/right** because when the bottle is opened, the pressure and concentration of carbon dioxide above the liquid phase decreases, so the equilibrium is shifted towards the formation of gaseous carbon dioxide.

**B) CO2(aq) + H2O(f) ⇌ H2CO3(aq)**This equilibrium is shifted to the **left/right** because due to the shift in the process indicated by A), the concentration of dissolved carbon dioxide decreases, leading to the decomposition of carbonic acid molecules.

**Experiment I:** Observe the following demonstration experiment.[[6]](#footnote-6) Write down your observations!

The Mentos candy has a strong foaming effect. About half of the cola has "come out" of the bottle.

Use your phone's camera to examine the surface of the Mentos candy you got at maximum magnification! What do you find?

The surface of the candy is not smooth and has crater-like indentations and bulges, which increase the specific surface area of the candy.

**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.**

**Experiment II:** Design experiments to find out what can cause gas to evolve in a carbonated liquid! Model (substitute) Coke and Mentos with the available substances!

MATERIALS AND EQUIPMENT: three 100 cm3 beakers or similar sized glass or plastic containers, tweezers, a piece of glass, a piece of terracotta (e.g. from a flower pot or a piece of brick), a piece of cloth, a smartphone or magnifying glass, carbonated mineral water or soda water.

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!**

Quality/specific surface area of solids placed in carbonated mineral water.

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

The intensity of gas evolution.

3. HOW CAN YOU TEST THIS DEPENDENT VARIABLE? We observe the rate of gas evolution and the amount of gas bubbles that form in the liquid.

4. THIS IS THE ASSUMPTION (HYPOTHESIS): The more uneven the surface of the solid placed in the mineral water, i.e. the higher the specific surface area, the more intense the formation of gas bubbles will be.

|  |  |  |
| --- | --- | --- |
| Experiment 1carbonated mineral water | Experiment 2carbonated mineral water + a piece of glass | Experiment 3carbonated mineral water + a piece of terracotta |
| number of repetitions in class: | number of repetitions in class: | number of repetitions in class: |

5. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark with an **X** sign!

[ ]  The shape of the glass vessel. [x]  The carbon dioxide content of the mineral water.

[ ]  The volume of the mineral water. [x]  The temperature of the mineral water.

6. THE STEPS OF THE EXPERIMENTS:

(1) We examine the surface of the piece of glass and the piece of terracotta with our phone's camera at the highest magnification possible.

(2) We carefully pour about the same volume of sparkling mineral water into the three glass jars.

(3) We use the carbonated mineral water in the first jar as a control.

(4) Using tweezers, we place the piece of glass in the second container.

(5) Using tweezers, we place the piece of terracotta in the third container.

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

7. OBSERVATIONS: A few bubbles are observed on the walls and bottom of the beaker used as a control, with one of them rarely rising to the surface. In beaker 2, gas bubbles are formed on the surface of the piece of glass and slowly separate from the piece of glass and rise to the surface. In beaker 3, a continuous, rapid evolution of gas is observed, which escapes from the liquid in the form of small bubbles.

8. Explanation: Surface roughness of solids increases the specific surface area of the solid. The pores of solids with a high specific surface area contain gas particles that act as a bubble nucleus in a solution supersaturated with carbon dioxide. The glass surface is **more even/ more uneven** and has a **smaller/higher** specific surface area than the terracotta, hence the rate of gas evolution on its surface is **lower/higher** than on the terracotta. Using the same volume and temperature of mineral water, the mineral water in the **first/second/third** beaker of the open systems in the experiment bubbles up carbon dioxide gas most rapidly.

CONCLUSION: The specific surface area of the Mentos candy passing through the digestive tract to the stomach **decreases/increases** due to the digestive juices, resembling more **a piece of glass/ a piece of terracotta**. Therefore, a **more violent/less violent** reaction takes place between the cola and the candy in the stomach than in the cola bottle. Our digestive tract is a **closed/open** system, so the gas produced in our stomach **can/can't escape** through the body orifices. The incident in this article **may/may not** have happened.

9. LET'S THINK!

"*Almost every brewer has come across a beer that behaves like a geyser, whether it's a home brew or a store-bought. Overflowing beer is a bad sign in itself, but in extreme bad cases the beer bottle can explode, although fortunately this is very rare. Opinions differ on how much pressure a beer bottle can withstand without exploding, as this varies from manufacturer to manufacturer. For most disposable beer bottles the tolerance is 2-4 bar, for reusable beer bottles it is 3-7 bar, and for champagne bottles it can be even higher."*

While carbon dioxide is added to soft drinks during production, in the beer and champagne mentioned in the quote above, carbon dioxide is produced as a by-product of fermentation. Complete the equation for the reaction of alcoholic fermentation with glucose. The formula for ethyl alcohol is C2H5OH.

C6H12O6 = **2 C2H5OH + 2 CO2**

Sealed beer/champagne bottles and cans are closed systems. Depending on the conditions of storage and transport, the ratio of dissolved to undissolved carbon dioxide may vary, so the pressure inside the bottle will also vary. Circle the arrows in the text that explain the increase in pressure in the bottle.

solubility of carbon dioxide ↑↓

the amount of gaseous carbon dioxide in the bottle ↑↓

temperature ↑↓

the pressure in the bottle ↑↓

END OF THE 16th STUDENT SHEETS AND TEACHER NOTES

**Student sheet** **17: Sour as vinegar**

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

Imagine you are on holiday in a house far from any shops or populated areas and you want to make a salad dressing. You find two green bottles of vinegar, which unfortunately have the labels falling off, so you don't know which is 10% and which is 20%. The salad dressing recipe calls for 10% vinegar, and a dressing made with 20% vinegar would obviously be unpalatably sour. Fortunately, you have bought red cabbage for the mixed salad, the juice of which can be used as an acid-base indicator. And in the house you have solid drain cleaner, which is sodium hydroxide in its main bulk, and from which you can make an alkaline solution. So, using your knowledge of chemistry, you could carry out the following experiment to determine which bottle contains the more dilute vinegar.

Vinegar bottles and cups in front of you are marked "A" and "B". The same volume of water was poured into each glass, then 1 drop of vinegar from the vinegar bottle marked "A" was added to glass "A" and 1 drop of vinegar from bottle "B" was added to glass "B". Carry out an experiment to determine which of the glasses contains the more dilute and which the more concentrated vinegar solution, and from this deduce which of the bottles contains the 10% vinegar needed to make the salad dressing. For identification, you have at your disposal the red cabbage juice indicator and the sodium hydroxide solution made by dissolving the drain cleaner in water.

MATERIALS AND EQUIPMENT: two acetic acid solutions with different concentrations in beakers “A” and “B”, drain cleaning solution (NaOH solution), red cabbage juice, 2 eye droppers/Pasteur pipettes, 2 glass sticks/spoons

|  |  |
| --- | --- |
| Experiment 1:vinegar solution in beaker marked "A" + red cabbage juice + NaOH solution dripped until blue colour is reached | Experiment 2:vinegar solution in beaker marked "B" + red cabbage juice + NaOH solution dripped until blue colour is reached |

STEPS OF THE EXPERIMENT

(1) Drip (equal amounts) of red cabbage juice into each glass.

(2) Drip NaOH solution first into beaker “A” and then into beaker “B” until the indicator turns blue.

(3) After each drop of NaOH solution is added, mix the solutions.

(4) For both solutions, record the number of drops of NaOH solution added.

**After the experiments are done, write down your observations and explanations. Draw a conclusion too.**

**Complete the text by entering the correct words or underlining the correct words.**

1. OBSERVATION:

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

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

2. Explanation:

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

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

3. Write the equation for the reaction of acetic acid and sodium hydroxide. Name the products!

CH3COOH + ……………………….. = ……………………….. + ………………………..

 ……………………….. ………………………..

4. CONCLUSION:

The glass marked "A"/"B" had the most dilute vinegar solution, so the vinegar in that bottle should be used to make the salad dressing.

5. LET’S THINK!

In June 2016, a 61-year-old woman living above a pizzeria in Kecskemét poured acid on students and their teacher who were talking in front of the restaurant. The woman was disturbed by the noise, so first she told them to leave from under her window or she would pour sulphuric acid on them, then she poured a bucket of corrosive substance on the street. The students' teacher was injured in the back, a woman in the leg and another in the head and face.

When corrosive material gets on the skin, it is important to administer first aid professionally and quickly. The corrosive effect of acids and bases depends on the concentration of oxonium ions and hydroxide ions, which in turn are always determined by two factors: the concentration of the acid or base and the strength of the acid or base. If a corrosive chemical (e.g. descaler, rust remover, drain cleaner) gets on the skin, it should be washed off immediately with plenty of water. In the case of acid burns, a weak and dilute base solution can be used to neutralise, but not concentrated and strong alkaline solutions, which would also be corrosive. In the case of an injury caused by an alkali, a weak and dilute acid solution should obviously be used. Since insects also release acidic or alkaline substances into the body when they bite, it is also appropriate to neutralise them by means of an appropriate acid-base reaction.

Draw a line in the table below to indicate the type of neutralizing solution to be used for each type of injury. (There may be several good solutions.)

|  |  |  |
| --- | --- | --- |
| **Cause of the injury** |  | **Neutralising solution** |
| concentrated drain cleaner solution (concentrated NaOH solution) |  | household hydrochloric acid (20%, relatively concentrated HCl) |
| household hydrochloric acid (20%, relatively concentrated HCl) |  | concentrated drain cleaner solution (concentrated NaOH solution) |
| rust remover (relatively concentrated phosphoric acid solution) |  | dilute solution of vinegar (CH3COOH solution) |
| descaler containing hydrochloric acid |  | dilute solution of sodium bicarbonate (NaHCO3 solution) |
| bee stings (acidic venom) |  | dilute solution of household ammonia (NH3 solution) |
| wasp sting (alkaline toxin) |  | dilute lemon juice (citric acid solution) |
| ant stings (acidic toxins, mainly HCOOH) |  | rust remover (relatively concentrated phosphoric acid solution) |

**Teacher notes for Student sheet 17: Sour as vinegar**

(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.

Imagine you are on holiday in a house far from any shops or populated areas and you want to make a salad dressing. You find two green bottles of vinegar, which unfortunately have the labels falling off, so you don't know which is 10% and which is 20%. The salad dressing recipe calls for 10% vinegar, and a dressing made with 20% vinegar would obviously be unpalatably sour. Fortunately, you have bought red cabbage for the mixed salad, the juice of which can be used as an acid-base indicator. And in the house you have solid drain cleaner, which is sodium hydroxide in its main bulk, and from which you can make an alkaline solution. So, using your knowledge of chemistry, you could carry out the following experiment to determine which bottle contains the more dilute vinegar.

Vinegar bottles and cups in front of you are marked "A" and "B". The same volume of water was poured into each glass, then 1 drop of vinegar from the vinegar bottle marked "A" was added to glass "A" and 1 drop of vinegar from bottle "B" was added to glass "B". Carry out an experiment to determine which of the glasses contains the more dilute and which the more concentrated vinegar solution, and from this deduce which of the bottles contains the 10% vinegar needed to make the salad dressing. For identification, you have at your disposal the red cabbage juice indicator and the sodium hydroxide solution made by dissolving the drain cleaner in water.

MATERIALS AND EQUIPMENT: two acetic acid solutions with different concentrations in beakers “A” and “B”, drain cleaning solution (NaOH solution), red cabbage juice, 2 eye droppers/Pasteur pipettes, 2 glass sticks/spoons

|  |  |
| --- | --- |
| Experiment 1:vinegar solution in beaker marked "A" + red cabbage juice + NaOH solution dripped until blue colour is reached | Experiment 2:vinegar solution in beaker marked "B" + red cabbage juice + NaOH solution dripped until blue colour is reached |

STEPS OF THE EXPERIMENT

(1) Drip (equal amounts) of red cabbage juice into each glass.

(2) Drip NaOH solution first into beaker “A” and then into beaker “B” until the indicator turns blue.

(3) After each drop of NaOH solution is added, mix the solutions.

(4) For both solutions, record the number of drops of NaOH solution added.

**After the experiments are done, write down your observations and explanations. Draw a conclusion too.**

**Complete the text by entering the correct words or underlining the correct words.**

1. OBSERVATION:

Experiment 1.: To the contents of beaker “A”, 32 drops of NaOH solution were added until the blue colour appeared.

Experiment 2.: To the contents of beaker “B”, 16 drops of NaOH solution were added until the blue colour appeared.

2. Explanation:

Experiment 1.: The solution in beaker „A” was made from 20% vinegar, because a larger volume of NaOH was needed to neutralise it.

Experiment 2.: The solution in beaker „B” was made from 10% vinegar, because a smaller volume of NaOH was needed to neutralise it.

3. Write the equation for the reaction of acetic acid and sodium hydroxide. Name the products!

CH3COOH + NaOH = CH3COONa + H2O

 sodium acetate water

4. CONCLUSION:

The glass marked "A"/"B" had the most dilute vinegar solution, so the vinegar in that bottle should be used to make the salad dressing.

5. LET’S THINK!

In June 2016, a 61-year-old woman living above a pizzeria in Kecskemét poured acid on students and their teacher who were talking in front of the restaurant. The woman was disturbed by the noise, so first she told them to leave from under her window or she would pour sulphuric acid on them, then she poured a bucket of corrosive substance on the street. The students' teacher was injured in the back, a woman in the leg and another in the head and face.

When corrosive material gets on the skin, it is important to administer first aid professionally and quickly. The corrosive effect of acids and bases depends on the concentration of oxonium ions and hydroxide ions, which in turn are always determined by two factors: the concentration of the acid or base and the strength of the acid or base. If a corrosive chemical (e.g. descaler, rust remover, drain cleaner) gets on the skin, it should be washed off immediately with plenty of water. In the case of acid burns, a weak and dilute base solution can be used to neutralise, but not concentrated and strong alkaline solutions, which would also be corrosive. In the case of an injury caused by an alkali, a weak and dilute acid solution should obviously be used. Since insects also release acidic or alkaline substances into the body when they bite, it is also appropriate to neutralise them by means of an appropriate acid-base reaction.

Draw a line in the table below to indicate the type of neutralizing solution to be used for each type of injury. (There may be several good solutions.)

|  |  |  |
| --- | --- | --- |
| **Cause of the injury** |  | **Neutralising solution** |
| concentrated drain cleaner solution (concentrated NaOH solution) |  | household hydrochloric acid (20%, relatively concentrated HCl) |
| household hydrochloric acid (20%, relatively concentrated HCl) |  | concentrated drain cleaner solution (concentrated NaOH solution) |
| rust remover (relatively concentrated phosphoric acid solution) |  | dilute solution of vinegar (CH3COOH solution) |
| descaler containing hydrochloric acid |  | dilute solution of sodium bicarbonate (NaHCO3 solution) |
| bee stings (acidic venom) |  | dilute solution of household ammonia (NH3 solution) |
| wasp sting (alkaline toxin) |  | dilute lemon juice (citric acid solution) |
| ant stings (acidic toxins, mainly HCOOH) |  | rust remover (relatively concentrated phosphoric acid solution) |

**Student sheet 17: Sour as vinegar**

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

Imagine you are on holiday in a house far from any shops or populated areas and you want to make a salad dressing. You find two green bottles of vinegar, which unfortunately have the labels falling off, so you don't know which is 10% and which is 20%. The salad dressing recipe calls for 10% vinegar, and a dressing made with 20% vinegar would obviously be unpalatably sour. Fortunately, you have bought red cabbage for the mixed salad, the juice of which can be used as an acid-base indicator. And in the house you have solid drain cleaner, which is sodium hydroxide in its main bulk, and from which you can make an alkaline solution. So, using your knowledge of chemistry, you could carry out the following experiment to determine which bottle contains the more dilute vinegar.

Vinegar bottles and cups in front of you are marked "A" and "B". The same volume of water was poured into each glass, then 1 drop of vinegar from the vinegar bottle marked "A" was added to glass "A" and 1 drop of vinegar from bottle "B" was added to glass "B". Carry out an experiment to determine which of the glasses contains the more dilute and which the more concentrated vinegar solution, and from this deduce which of the bottles contains the 10% vinegar needed to make the salad dressing. For identification, you have at your disposal the red cabbage juice indicator and the sodium hydroxide solution made by dissolving the drain cleaner in water.

MATERIALS AND EQUIPMENT: two acetic acid solutions with different concentrations in beakers “A” and “B”, drain cleaning solution (NaOH solution), red cabbage juice, 2 eye droppers/Pasteur pipettes, 2 glass sticks/spoons

|  |  |
| --- | --- |
| Experiment 1:vinegar solution in beaker marked "A" + red cabbage juice + NaOH solution dripped until blue colour is reached | Experiment 2:vinegar solution in beaker marked "B" + red cabbage juice + NaOH solution dripped until blue colour is reached |

STEPS OF THE EXPERIMENT

(1) Drip (equal amounts) of red cabbage juice into each glass.

(2) Drip NaOH solution first into beaker “A” and then into beaker “B” until the indicator turns blue.

(3) After each drop of NaOH solution is added, mix the solutions.

(4) For both solutions, record the number of drops of NaOH solution added.

**After the experiments are done, write down your observations and explanations. Draw a conclusion too.**

**Complete the text by entering the correct words or underlining the correct words.**

1. OBSERVATION:

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

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

2. Explanation:

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

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

3. Write the equation for the reaction of acetic acid and sodium hydroxide. Name the products!

CH3COOH + ……………………….. = ……………………….. + ………………………..

 ……………………….. ………………………..

4. CONCLUSION:

The glass marked "A"/"B" had the most dilute vinegar solution, so the vinegar in that bottle should be used to make the salad dressing.

**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.**

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!

[ ]  Volume of the glass [ ]  Substances in the indicator

[ ]  The colour of the solution after the addition of the NaOH solution [ ]  Concentration of the NaOH solution

[ ]  The dropper used to dispense the NaOH solution

10. LET’S THINK!

In June 2016, a 61-year-old woman living above a pizzeria in Kecskemét poured acid on students and their teacher who were talking in front of the restaurant. The woman was disturbed by the noise, so first she told them to leave from under her window or she would pour sulphuric acid on them, then she poured a bucket of corrosive substance on the street. The students' teacher was injured in the back, a woman in the leg and another in the head and face.

When corrosive material gets on the skin, it is important to administer first aid professionally and quickly. The corrosive effect of acids and bases depends on the concentration of oxonium ions and hydroxide ions, which in turn are always determined by two factors: the concentration of the acid or base and the strength of the acid or base. If a corrosive chemical (e.g. descaler, rust remover, drain cleaner) gets on the skin, it should be washed off immediately with plenty of water. In the case of acid burns, a weak and dilute base solution can be used to neutralise, but not concentrated and strong alkaline solutions, which would also be corrosive. In the case of an injury caused by an alkali, a weak and dilute acid solution should obviously be used. Since insects also release acidic or alkaline substances into the body when they bite, it is also appropriate to neutralise them by means of an appropriate acid-base reaction.

Draw a line in the table below to indicate the type of neutralizing solution to be used for each type of injury. (There may be several good solutions.)

|  |  |  |
| --- | --- | --- |
| **Cause of the injury** |  | **Neutralising solution** |
| concentrated drain cleaner solution (concentrated NaOH solution) |  | household hydrochloric acid (20%, relatively concentrated HCl) |
| household hydrochloric acid (20%, relatively concentrated HCl) |  | concentrated drain cleaner solution (concentrated NaOH solution) |
| rust remover (relatively concentrated phosphoric acid solution) |  | dilute solution of vinegar (CH3COOH solution) |
| descaler containing hydrochloric acid |  | dilute solution of sodium bicarbonate (NaHCO3 solution) |
| bee stings (acidic venom) |  | dilute solution of household ammonia (NH3 solution) |
| wasp sting (alkaline toxin) |  | dilute lemon juice (citric acid solution) |
| ant stings (acidic toxins, mainly HCOOH) |  | rust remover (relatively concentrated phosphoric acid solution) |

**Teacher notes for Student sheet 17: Sour as vinegar**

(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.

Imagine you are on holiday in a house far from any shops or populated areas and you want to make a salad dressing. You find two green bottles of vinegar, which unfortunately have the labels falling off, so you don't know which is 10% and which is 20%. The salad dressing recipe calls for 10% vinegar, and a dressing made with 20% vinegar would obviously be unpalatably sour. Fortunately, you have bought red cabbage for the mixed salad, the juice of which can be used as an acid-base indicator. And in the house you have solid drain cleaner, which is sodium hydroxide in its main bulk, and from which you can make an alkaline solution. So, using your knowledge of chemistry, you could carry out the following experiment to determine which bottle contains the more dilute vinegar.

Vinegar bottles and cups in front of you are marked "A" and "B". The same volume of water was poured into each glass, then 1 drop of vinegar from the vinegar bottle marked "A" was added to glass "A" and 1 drop of vinegar from bottle "B" was added to glass "B". Carry out an experiment to determine which of the glasses contains the more dilute and which the more concentrated vinegar solution, and from this deduce which of the bottles contains the 10% vinegar needed to make the salad dressing. For identification, you have at your disposal the red cabbage juice indicator and the sodium hydroxide solution made by dissolving the drain cleaner in water.

MATERIALS AND EQUIPMENT: two acetic acid solutions with different concentrations in beakers “A” and “B”, drain cleaning solution (NaOH solution), red cabbage juice, 2 eye droppers/Pasteur pipettes, 2 glass sticks/spoons

|  |  |
| --- | --- |
| Experiment 1:vinegar solution in beaker marked "A" + red cabbage juice + NaOH solution dripped until blue colour is reached | Experiment 2:vinegar solution in beaker marked "B" + red cabbage juice + NaOH solution dripped until blue colour is reached |

STEPS OF THE EXPERIMENT

(1) Drip (equal amounts) of red cabbage juice into each glass.

(2) Drip NaOH solution first into beaker “A” and then into beaker “B” until the indicator turns blue.

(3) After each drop of NaOH solution is added, mix the solutions.

(4) For both solutions, record the number of drops of NaOH solution added.

**After the experiments are done, write down your observations and explanations. Draw a conclusion too.**

**Complete the text by entering the correct words or underlining the correct words.**

1. OBSERVATION:

Experiment 1.: To the contents of beaker “A”, 32 drops of NaOH solution were added until the blue colour appeared.

Experiment 2.: To the contents of beaker “B”, 16 drops of NaOH solution were added until the blue colour appeared.

2. Explanation:

Experiment 1.: The solution in beaker „A” was made from 20% vinegar, because a larger volume of NaOH was needed to neutralise it.

Experiment 2.: The solution in beaker „B” was made from 10% vinegar, because a smaller volume of NaOH was needed to neutralise it.

3. Write the equation for the reaction of acetic acid and sodium hydroxide. Name the products!

CH3COOH + NaOH = CH3COONa + H2O

 sodium acetate water

4. CONCLUSION:

The glass marked "A"/"B" had the most dilute vinegar solution, so the vinegar in that bottle should be used to make the salad dressing.

**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.**

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 concentration of vinegar added to water.

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

Volume of NaOH solution of the same concentration required for neutralisation.

7. HOW COULD YOU TEST THIS DEPENDENT VARIABLE? For both acetic acid solutions, the number of droplets of NaOH solution required to obtain the same shade of colour of the indicator was counted.

8. THIS WAS THE ASSUMPTION (HYPOTHESIS):

If the vinegar solution is more concentrated (the independent variable changes as intended), then more drops of NaOH solution required for neutralisation (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!

[ ]  Volume of the glass [x]  Substances in the indicator

[x]  The colour of the solution after the addition of the NaOH solution [x]  Concentration of the NaOH solution

[x]  The dropper used to dispense the NaOH solution

10. LET'S THINK!

In June 2016, a 61-year-old woman living above a pizzeria in Kecskemét poured acid on students and their teacher who were talking in front of the restaurant. The woman was disturbed by the noise, so first she told them to leave from under her window or she would pour sulphuric acid on them, then she poured a bucket of corrosive substance on the street. The students' teacher was injured in the back, a woman in the leg and another in the head and face.

When corrosive material gets on the skin, it is important to administer first aid professionally and quickly. The corrosive effect of acids and bases depends on the concentration of oxonium ions and hydroxide ions, which in turn are always determined by two factors: the concentration of the acid or base and the strength of the acid or base. If a corrosive chemical (e.g. descaler, rust remover, drain cleaner) gets on the skin, it should be washed off immediately with plenty of water. In the case of acid burns, a weak and dilute base solution can be used to neutralise, but not concentrated and strong alkaline solutions, which would also be corrosive. In the case of an injury caused by an alkali, a weak and dilute acid solution should obviously be used. Since insects also release acidic or alkaline substances into the body when they bite, it is also appropriate to neutralise them by means of an appropriate acid-base reaction.

Draw a line in the table below to indicate the type of neutralizing solution to be used for each type of injury. (There may be several good solutions.)

|  |  |  |
| --- | --- | --- |
| **Cause of the injury** |  | **Neutralising solution** |
| concentrated drain cleaner solution (concentrated NaOH solution) |  | household hydrochloric acid (20%, relatively concentrated HCl) |
| household hydrochloric acid (20%, relatively concentrated HCl) |  | concentrated drain cleaner solution (concentrated NaOH solution) |
| rust remover (relatively concentrated phosphoric acid solution) |  | dilute solution of vinegar (CH3COOH solution) |
| descaler containing hydrochloric acid |  | dilute solution of sodium bicarbonate (NaHCO3 solution) |
| bee stings (acidic venom) |  | dilute solution of household ammonia (NH3 solution) |
| wasp sting (alkaline toxin) |  | dilute lemon juice (citric acid solution) |
| ant stings (acidic toxins, mainly HCOOH) |  | rust remover (relatively concentrated phosphoric acid solution) |

**Student sheet 17: Sour as vinegar**

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

Imagine you are on holiday in a house far from any shops or populated areas and you want to make a salad dressing. You find two green bottles of vinegar, which unfortunately have the labels falling off, so you don't know which is 10% and which is 20%. The salad dressing recipe calls for 10% vinegar, and a dressing made with 20% vinegar would obviously be unpalatably sour. Fortunately, you have bought red cabbage for the mixed salad, the juice of which can be used as an acid-base indicator. And in the house you have solid drain cleaner, which is sodium hydroxide in its main bulk, and from which you can make an alkaline solution. So, using your knowledge of chemistry, you could carry out the following experiment to determine which bottle contains the more dilute vinegar.

Vinegar bottles and cups in front of you are marked "A" and "B". The same volume of water was poured into each glass, then 1 drop of vinegar from the vinegar bottle marked "A" was added to glass "A" and 1 drop of vinegar from bottle "B" was added to glass "B". Design an experiment to determine **which of the glasses contains the more dilute and which the more concentrated vinegar solution, and from this deduce which of the bottles contains the 10% vinegar needed to make the salad dressing**. For identification, you have at your disposal the red cabbage juice indicator and the sodium hydroxide solution made by dissolving the drain cleaner in water.

MATERIALS AND EQUIPMENT: two acetic acid solutions with different concentrations in beakers “A” and “B”, drain cleaning solution (NaOH solution), red cabbage juice, 2 eye droppers/Pasteur pipettes, 2 glass sticks/spoons

**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 beaker.

|  |  |
| --- | --- |
| 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 **X** sign!

[ ]  Volume of the glass [ ]  Substances in the indicator

[ ]  The colour of the solution after the addition of the NaOH solution [ ]  Concentration of the NaOH solution

[ ]  The dropper used to dispense the NaOH solution

7. THE STEPS OF THE EXPERIMENTS:

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

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

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

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

**After the experiments are done, write down your observations and explanations. Draw a conclusion too.**

**Complete the text by entering the correct words or underlining the correct words.**

8. OBSERVATION:

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

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

9. Explanation:

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

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

10. Write the equation for the reaction of acetic acid and sodium hydroxide. Name the products!

CH3COOH + ……………………….. = ……………………….. + ………………………..

 ……………………….. ………………………..

11. CONCLUSION:

The glass marked "A"/"B" had the most dilute vinegar solution, so the vinegar in that bottle should be used to make the salad dressing.

12. LET’S THINK!

In June 2016, a 61-year-old woman living above a pizzeria in Kecskemét poured acid on students and their teacher who were talking in front of the restaurant. The woman was disturbed by the noise, so first she told them to leave from under her window or she would pour sulphuric acid on them, then she poured a bucket of corrosive substance on the street. The students' teacher was injured in the back, a woman in the leg and another in the head and face.

When corrosive material gets on the skin, it is important to administer first aid professionally and quickly. The corrosive effect of acids and bases depends on the concentration of oxonium ions and hydroxide ions, which in turn are always determined by two factors: the concentration of the acid or base and the strength of the acid or base. If a corrosive chemical (e.g. descaler, rust remover, drain cleaner) gets on the skin, it should be washed off immediately with plenty of water. In the case of acid burns, a weak and dilute base solution can be used to neutralise, but not concentrated and strong alkaline solutions, which would also be corrosive. In the case of an injury caused by an alkali, a weak and dilute acid solution should obviously be used. Since insects also release acidic or alkaline substances into the body when they bite, it is also appropriate to neutralise them by means of an appropriate acid-base reaction.

Draw a line in the table below to indicate the type of neutralizing solution to be used for each type of injury. (There may be several good solutions.)

|  |  |  |
| --- | --- | --- |
| **Cause of the injury** |  | **Neutralising solution** |
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| household hydrochloric acid (20%, relatively concentrated HCl) |  | concentrated drain cleaner solution (concentrated NaOH solution) |
| rust remover (relatively concentrated phosphoric acid solution) |  | dilute solution of vinegar (CH3COOH solution) |
| descaler containing hydrochloric acid |  | dilute solution of sodium bicarbonate (NaHCO3 solution) |
| bee stings (acidic venom) |  | dilute solution of household ammonia (NH3 solution) |
| wasp sting (alkaline toxin) |  | dilute lemon juice (citric acid solution) |
| ant stings (acidic toxins, mainly HCOOH) |  | rust remover (relatively concentrated phosphoric acid solution) |

**Teacher notes for Student sheet 17: Sour as vinegar**

(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.

Imagine you are on holiday in a house far from any shops or populated areas and you want to make a salad dressing. You find two green bottles of vinegar, which unfortunately have the labels falling off, so you don't know which is 10% and which is 20%. The salad dressing recipe calls for 10% vinegar, and a dressing made with 20% vinegar would obviously be unpalatably sour. Fortunately, you have bought red cabbage for the mixed salad, the juice of which can be used as an acid-base indicator. And in the house you have solid drain cleaner, which is sodium hydroxide in its main bulk, and from which you can make an alkaline solution. So, using your knowledge of chemistry, you could carry out the following experiment to determine which bottle contains the more dilute vinegar.

Vinegar bottles and cups in front of you are marked "A" and "B". The same volume of water was poured into each glass, then 1 drop of vinegar from the vinegar bottle marked "A" was added to glass "A" and 1 drop of vinegar from bottle "B" was added to glass "B". Design an experiment to determine **which of the glasses contains the more dilute and which the more concentrated vinegar solution, and from this deduce which of the bottles contains the 10% vinegar needed to make the salad dressing**. For identification, you have at your disposal the red cabbage juice indicator and the sodium hydroxide solution made by dissolving the drain cleaner in water.

MATERIALS AND EQUIPMENT: two acetic acid solutions with different concentrations in beakers “A” and “B”, drain cleaning solution (NaOH solution), red cabbage juice, 2 eye droppers/Pasteur pipettes, 2 glass sticks/spoons

**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 concentration of vinegar added to water.

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

Volume of NaOH solution of the same concentration required for neutralisation.

3. HOW CAN YOU TEST THIS DEPENDENT VARIABLE? For both acetic acid solutions, the number of droplets of NaOH solution required to obtain the same shade of colour of the indicator should be counted.

4. THIS IS THE ASSUMPTION (HYPOTHESIS): If the vinegar solution is more concentrated (the independent variable changes as intended), then more drops of NaOH solution required for neutralisation (the dependent variable will change in this way).

5. HOW CAN THE INDEPENDENT VARIABLE CHANGE? Plan what to put in the beakers.

|  |  |
| --- | --- |
| Experiment 1:vinegar solution in beaker marked "A" + red cabbage juice + NaOH solution dripped until blue colour is reached | Experiment 2:vinegar solution in beaker marked "B" + red cabbage juice + NaOH solution dripped until blue colour is reached |
| 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 **X** sign!

[ ]  Volume of the glass [x]  Substances in the indicator

[x]  The colour of the solution after the addition of the NaOH solution [x]  Concentration of the NaOH solution

[x]  The dropper used to dispense the NaOH solution

7. THE STEPS OF THE EXPERIMENTS:

(1) Drip (equal amounts) of red cabbage juice into each glass.

(2) Drip NaOH solution first into beaker “A” and then into beaker “B” until the indicator turns blue.

(3) After each drop of NaOH solution is added, mix the solutions.

(4) For both solutions, record the number of drops of NaOH solution added.

**After the experiments are done, write down your observations and explanations. Draw a conclusion too.**

**Complete the text by entering the correct words or underlining the correct words.**

8. OBSERVATION:

Experiment 1.: To the contents of beaker “A”, 32 drops of NaOH solution were added until the blue colour appeared.

Experiment 2.: To the contents of beaker “B”, 16 drops of NaOH solution were added until the blue colour appeared.

9. Explanation:

Experiment 1.: The solution in beaker „A” was made from 20% vinegar, because a larger volume of NaOH was needed to neutralise it.

Experiment 2.: The solution in beaker „B” was made from 10% vinegar, because a smaller volume of NaOH was needed to neutralise it.

10. Write the equation for the reaction of acetic acid and sodium hydroxide. Name the products!

CH3COOH + NaOH = CH3COONa + H2O

 sodium acetate water

11. CONCLUSION:

The glass marked "A"/"B" had the most dilute vinegar solution, so the vinegar in that bottle should be used to make the salad dressing.

12. LET’S THINK!

In June 2016, a 61-year-old woman living above a pizzeria in Kecskemét poured acid on students and their teacher who were talking in front of the restaurant. The woman was disturbed by the noise, so first she told them to leave from under her window or she would pour sulphuric acid on them, then she poured a bucket of corrosive substance on the street. The students' teacher was injured in the back, a woman in the leg and another in the head and face.

When corrosive material gets on the skin, it is important to administer first aid professionally and quickly. The corrosive effect of acids and bases depends on the concentration of oxonium ions and hydroxide ions, which in turn are always determined by two factors: the concentration of the acid or base and the strength of the acid or base. If a corrosive chemical (e.g. descaler, rust remover, drain cleaner) gets on the skin, it should be washed off immediately with plenty of water. In the case of acid burns, a weak and dilute base solution can be used to neutralise, but not concentrated and strong alkaline solutions, which would also be corrosive. In the case of an injury caused by an alkali, a weak and dilute acid solution should obviously be used. Since insects also release acidic or alkaline substances into the body when they bite, it is also appropriate to neutralise them by means of an appropriate acid-base reaction.

Draw a line in the table below to indicate the type of neutralizing solution to be used for each type of injury. (There may be several good solutions.)

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| --- | --- | --- |
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| household hydrochloric acid (20%, relatively concentrated HCl) |  | concentrated drain cleaner solution (concentrated NaOH solution) |
| rust remover (relatively concentrated phosphoric acid solution) |  | dilute solution of vinegar (CH3COOH solution) |
| descaler containing hydrochloric acid |  | dilute solution of sodium bicarbonate (NaHCO3 solution) |
| bee stings (acidic venom) |  | dilute solution of household ammonia (NH3 solution) |
| wasp sting (alkaline toxin) |  | dilute lemon juice (citric acid solution) |
| ant stings (acidic toxins, mainly HCOOH) |  | rust remover (relatively concentrated phosphoric acid solution) |

END OF THE 17th STUDENT SHEETS AND TEACHER NOTES

**Student sheet 18: Hydrogen peroxide as a "miracle cure"?**

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

"*Previously used as a throat gargle and known for its antiseptic properties, it has now been found to cleanse blood vessels, oxygenate the blood and can be used to treat cardiovascular diseases; ..., it can be used as an anti-inflammatory, but it is also an effective medicine for oncological diseases.*" – as we can read in József Kovács's book "Hydrogen peroxide, the hidden medicine"[[7]](#footnote-7).

From time to time in recent years, similar fake news about hydrogen peroxide has surfaced, claiming that it can cure almost any disease, even cancer. This would imply that the coronavirus would not have been a problem if we had believed the recent pseudoscientific articles... But hydrogen peroxide is only an external disinfectant, it should not be ingested! It is an interesting substance because, depending on the reactant with which it is in contact, it can act either as an oxidising agent or as a reducing agent in redox reactions. **We will now look at how experiments can show whether hydrogen peroxide acts as an oxidising or reducing agent.**

**Indicate the correct answer by underlining or framing the bold words, or by ~~crossing out~~ the incorrect ones.**

When elemental oxygen gas is produced from hydrogen peroxide by giving off electrons, hydrogen peroxide is **oxidised/reduced** and is therefore an **oxidising/reducing** agent.

MATERIALS AND EQUIPMENT: distilled water, potassium iodide solution, sodium hypochlorite solution, hydrogen peroxide solution made of Hyperol tablet in beaker, 3 test tubes in rack, wooden splint, alcohol burner, matches, watch glass.

EXPERIMENT:

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):distilled water + hydrogen peroxide solution made of Hyperol tablet + glowing splint | Experiment 2: e.g. sodium hypochlorite solution + hydrogen peroxide solution made of Hyperol tablet + glowing splint | Experiment 3: e.g. potassium iodide solution + hydrogen peroxide solution made of Hyperol tablet + glowing splint |

STEPS OF THE EXPERIMENT

(1) Light the alcohol burner, then make a glowing splint.

(2) Add cca. 4 cm3 hydrogen peroxide solution to the distilled water in the test tube, and after about 10 seconds, insert the glowing splint into the test tube.

(3) Repeat the experiment with the other two test tubes of sodium hypochlorite solution and the potassium iodide solution.

**After carrying out the experiments, write down your experience, explanation and conclusion.**

1. OBSERVATION:

(1): ……………………………………………………………………………………………………………………………………………………………………….

(2): ……………………………………………………………………………………………………………………………………………………………………….

(3): ……………………………………………………………………………………………………………………………………………………………………….

2. Explanation:

(1): ……………………………………………………………………………………………………………………………………………………………………….

(2): ……………………………………………………………………………………………………………………………………………………………………….

(3): ……………………………………………………………………………………………………………………………………………………………………….

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

4. LET’S THINK!

Like hydrogen peroxide, hypochlorite is used for disinfection and decolourisation. However, the use of hypochlorite has its own dangers.

"*The Health Toxicology Information Service reported 101 cases of chlorine poisoning last year. The majority of these accidents occur in households, which is why it is important to be careful when using hypochlorite containing and acidic cleaning products.*" - can be read on the website hazipatika.com.

And the blikk.hu website writes the following:

"*Chlorine-based disinfectants and cleaning products used in households do not pose a risk when used alone, as prescribed. The problem arises if you want to increase their effect by simultaneously pouring a descaling agent or other chemical onto the surface to be cleaned. In this case, a chemical reaction produces chlorine gas, which can cause serious symptoms if inhaled*."

The active ingredient in hypochlorite is .........................................................................................., which produces

............................................................ when used together with hydrochloric acid. The resulting compound forms

............................................................ in an equilibrium reaction with hydrochloric acid.

Write down the two reaction equations mentioned above and then circle the corresponding arrows in the diagram below, recalling what you have learned about the reactions that lead to equilibrium.

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

the amount of chlorine gas formed

concentration of hydronium ion

the amount of chlorine gas released into the air

the amount of chlorine gas in the solution

↑↓

↑↓

↑↓

↑↓

addition of acid

**Teacher notes for Student sheet 18: Hydrogen peroxide as a "miracle cure"?**

(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.

"*Previously used as a throat gargle and known for its antiseptic properties, it has now been found to cleanse blood vessels, oxygenate the blood and can be used to treat cardiovascular diseases; ..., it can be used as an anti-inflammatory, but it is also an effective medicine for oncological diseases.*" – as we can read in József Kovács's book "Hydrogen peroxide, the hidden medicine"[[8]](#footnote-8).

From time to time in recent years, similar fake news about hydrogen peroxide has surfaced, claiming that it can cure almost any disease, even cancer. This would imply that the coronavirus would not have been a problem if we had believed the recent pseudoscientific articles... But hydrogen peroxide is only an external disinfectant, it should not be ingested! It is an interesting substance because, depending on the reactant with which it is in contact, it can act either as an oxidising agent or as a reducing agent in redox reactions. **We will now look at how experiments can show whether hydrogen peroxide acts as an oxidising or reducing agent.**

**Indicate the correct answer by underlining or framing the bold words, or by ~~crossing out~~ the incorrect ones.**

When elemental oxygen gas is produced from hydrogen peroxide by giving off electrons, hydrogen peroxide is **oxidised/reduced** and is therefore an **oxidising/reducing** agent.

MATERIALS AND EQUIPMENT: distilled water, potassium iodide solution, sodium hypochlorite solution, hydrogen peroxide solution made of Hyperol tablet in beaker, 3 test tubes in rack, wooden splint, alcohol burner, matches, watch glass.

EXPERIMENT:

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):distilled water + hydrogen peroxide solution made of Hyperol tablet + glowing splint | Experiment 2: e.g. sodium hypochlorite solution + hydrogen peroxide solution made of Hyperol tablet + glowing splint | Experiment 3: e.g. potassium iodide solution + hydrogen peroxide solution made of Hyperol tablet + glowing splint |

STEPS OF THE EXPERIMENT

(1) Light the alcohol burner, then make a glowing splint.

(2) Add cca. 4 cm3 hydrogen peroxide solution to the distilled water in the test tube, and after about 10 seconds, insert the glowing splint into the test tube.

(3) Repeat the experiment with the other two test tubes of sodium hypochlorite solution and the potassium iodide solution.

**After carrying out the experiments, write down your experience, explanation and conclusion.**

1. OBSERVATION:

(1): No change is observed for distilled water.

(2): In the case of hypochlorite, bubbles are formed, the colourless gas causes the glowing splint to glow/ignite with a crackling sound.

(3): In the case of potassium iodide solution, the solution turns brown, the glowing splint remains unchanged.

2. Explanation:

(1): Distilled water only dilutes the Hyperol solution. No chemical reaction occurs.

(2) Sodium hypochlorite in the hypo reacts with hydrogen peroxide. Oxygen is formed from hydrogen peroxide because sodium hypochlorite is a stronger oxidizing agent than hydrogen peroxide. The oxygen formed causes the glowing splint to glow/ignite. The reaction equation is H2O2 + ClO- = O2 + Cl- + H2O

(3) The iodide ions in the potassium iodide solution are oxidised by hydrogen peroxide to form elemental iodine. The brown colour of iodine is seen. The reaction equation is H2O2 + 2 I- = I2 + 2 OH-

3. CONCLUSION: Hydrogen peroxide acts as a reducing agent for sodium hypochlorite and as an oxidising agent for potassium iodide.

4. LET’S THINK!

Like hydrogen peroxide, hypochlorite is used for disinfection and decolourisation. However, the use of hypochlorite has its own dangers.

"*The Health Toxicology Information Service reported 101 cases of chlorine poisoning last year. The majority of these accidents occur in households, which is why it is important to be careful when using hypochlorite containing and acidic cleaning products.*" - can be read on the website hazipatika.com.

And the blikk.hu website writes the following:

"*Chlorine-based disinfectants and cleaning products used in households do not pose a risk when used alone, as prescribed. The problem arises if you want to increase their effect by simultaneously pouring a descaling agent or other chemical onto the surface to be cleaned. In this case, a chemical reaction produces chlorine gas, which can cause serious symptoms if inhaled*."

The active ingredient in hypochlorite is sodium hypochlorite, which produces hypochlorous acid when used together with hydrochloric acid. The resulting compound forms chlorine gas in an equilibrium reaction with hydrochloric acid.

Write down the two reaction equations mentioned above and then circle the corresponding arrows in the diagram below, recalling what you have learned about the reactions that lead to equilibrium.

NaOCl + HCl = HOCl + NaCl HOCl + HCl ⇌ Cl2 + H2O

↑ ↓

the amount of chlorine gas formed

concentration of hydronium ion

the amount of chlorine gas released into the air

the amount of chlorine gas in the solution

addition of acid

↑ ↓

↑ ↓

↑ ↓

**Student sheet 18: Hydrogen peroxide as a "miracle cure"?**

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

"*Previously used as a throat gargle and known for its antiseptic properties, it has now been found to cleanse blood vessels, oxygenate the blood and can be used to treat cardiovascular diseases; ..., it can be used as an anti-inflammatory, but it is also an effective medicine for oncological diseases.*" – as we can read in József Kovács's book "Hydrogen peroxide, the hidden medicine"[[9]](#footnote-9).

From time to time in recent years, similar fake news about hydrogen peroxide has surfaced, claiming that it can cure almost any disease, even cancer. This would imply that the coronavirus would not have been a problem if we had believed the recent pseudoscientific articles... But hydrogen peroxide is only an external disinfectant, it should not be ingested! It is an interesting substance because, depending on the reactant with which it is in contact, it can act either as an oxidising agent or as a reducing agent in redox reactions. **We will now look at how experiments can show whether hydrogen peroxide acts as an oxidising or reducing agent.**

**Indicate the correct answer by underlining or framing the bold words, or by ~~crossing out~~ the incorrect ones.**

When elemental oxygen gas is produced from hydrogen peroxide by giving off electrons, hydrogen peroxide is **oxidised/reduced** and is therefore an **oxidising/reducing** agent.

MATERIALS AND EQUIPMENT: distilled water, potassium iodide solution, sodium hypochlorite solution, hydrogen peroxide solution made of Hyperol tablet in beaker, 3 test tubes in rack, wooden splint, alcohol burner, matches, watch glass.

EXPERIMENT:

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):distilled water + hydrogen peroxide solution made of Hyperol tablet + glowing splint | Experiment 2: e.g. sodium hypochlorite solution + hydrogen peroxide solution made of Hyperol tablet + glowing splint | Experiment 3: e.g. potassium iodide solution + hydrogen peroxide solution made of Hyperol tablet + glowing splint |

STEPS OF THE EXPERIMENT

(1) Light the alcohol burner, then make a glowing splint.

(2) Add cca. 4 cm3 hydrogen peroxide solution to the distilled water in the test tube, and after about 10 seconds, insert the glowing splint into the test tube.

(3) Repeat the experiment with the other two test tubes of sodium hypochlorite solution and the potassium iodide solution.

**After carrying out the experiments, write down your experience, explanation and conclusion.**

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 it with ✚! Which(s) did not have to be the same, mark with ➖!

[ ]  Time elapsed between addition of the reagent and holding the glowing splint; [ ]  Volume of Hyperol solution; [ ]  Volume of test tube; [ ]  Length of glowing splint

9. LET'S THINK!

Like hydrogen peroxide, hypochlorite is used for disinfection and decolourisation. However, the use of hypochlorite has its own dangers.

"*The Health Toxicology Information Service reported 101 cases of chlorine poisoning last year. The majority of these accidents occur in households, which is why it is important to be careful when using hypochlorite containing and acidic cleaning products.*" - can be read on the website hazipatika.com.

And the blikk.hu website writes the following:

"*Chlorine-based disinfectants and cleaning products used in households do not pose a risk when used alone, as prescribed. The problem arises if you want to increase their effect by simultaneously pouring a descaling agent or other chemical onto the surface to be cleaned. In this case, a chemical reaction produces chlorine gas, which can cause serious symptoms if inhaled*."

The active ingredient in hypochlorite is .........................................................................................., which produces

............................................................ when used together with hydrochloric acid. The resulting compound forms

............................................................ in an equilibrium reaction with hydrochloric acid.

Write down the two reaction equations mentioned above and then circle the corresponding arrows in the diagram below, recalling what you have learned about the reactions that lead to equilibrium.

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

the amount of chlorine gas formed

concentration of hydronium ion

the amount of chlorine gas released into the air

the amount of chlorine gas in the solution

↑↓

↑↓

↑↓

↑↓

addition of acid

**Teacher notes for Student sheet 18: Hydrogen peroxide as a "miracle cure"?**

(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.

"*Previously used as a throat gargle and known for its antiseptic properties, it has now been found to cleanse blood vessels, oxygenate the blood and can be used to treat cardiovascular diseases; ..., it can be used as an anti-inflammatory, but it is also an effective medicine for oncological diseases.*" – as we can read in József Kovács's book "Hydrogen peroxide, the hidden medicine"[[10]](#footnote-10).

From time to time in recent years, similar fake news about hydrogen peroxide has surfaced, claiming that it can cure almost any disease, even cancer. This would imply that the coronavirus would not have been a problem if we had believed the recent pseudoscientific articles... But hydrogen peroxide is only an external disinfectant, it should not be ingested! It is an interesting substance because, depending on the reactant with which it is in contact, it can act either as an oxidising agent or as a reducing agent in redox reactions. **We will now look at how experiments can show whether hydrogen peroxide acts as an oxidising or reducing agent.**

**Indicate the correct answer by underlining or framing the bold words, or by ~~crossing out~~ the incorrect ones.**

When elemental oxygen gas is produced from hydrogen peroxide by giving off electrons, hydrogen peroxide is **oxidised/reduced** and is therefore an **oxidising/reducing** agent.

MATERIALS AND EQUIPMENT: distilled water, potassium iodide solution, sodium hypochlorite solution, hydrogen peroxide solution made of Hyperol tablet in beaker, 3 test tubes in rack, wooden splint, alcohol burner, matches, watch glass.

EXPERIMENT:

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):distilled water + hydrogen peroxide solution made of Hyperol tablet + glowing splint | Experiment 2: e.g. sodium hypochlorite solution + hydrogen peroxide solution made of Hyperol tablet + glowing splint | Experiment 3: e.g. potassium iodide solution + hydrogen peroxide solution made of Hyperol tablet + glowing splint |

STEPS OF THE EXPERIMENT

(1) Light the alcohol burner, then make a glowing splint.

(2) Add cca. 4 cm3 hydrogen peroxide solution to the distilled water in the test tube, and after about 10 seconds, insert the glowing splint into the test tube.

(3) Repeat the experiment with the other two test tubes of sodium hypochlorite solution and the potassium iodide solution.

**After carrying out the experiments, write down your experience, explanation and conclusion.**

1. OBSERVATION:

(1): No change is observed for distilled water.

(2): In the case of hypochlorite, bubbles are formed, the colourless gas causes the glowing splint to glow/ignite with a crackling sound.

(3): In the case of potassium iodide solution, the solution turns brown, the glowing splint remains unchanged.

2. Explanation:

(1): Distilled water only dilutes the Hyperol solution. No chemical reaction occurs.

(2) Sodium hypochlorite in the hypo reacts with hydrogen peroxide. Oxygen is formed from hydrogen peroxide because sodium hypochlorite is a stronger oxidizing agent than hydrogen peroxide. The oxygen formed causes the glowing splint to glow/ignite. The reaction equation is H2O2 + ClO- = O2 + Cl- + H2O

(3) The iodide ions in the potassium iodide solution are oxidised by hydrogen peroxide to form elemental iodine. The brown colour of iodine is seen. The reaction equation is H2O2 + 2 I- = I2 + 2 OH-

3. CONCLUSION: Hydrogen peroxide acts as a reducing agent for sodium hypochlorite and as an oxidising agent for potassium iodide.

**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 chemical reagent used in the experiment, reacted with hydrogen peroxide.

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

Whether hydrogen peroxide acts as an oxidising or reducing agent.

6. HOW COULD YOU TEST THIS DEPENDENT VARIABLE?

Through the behaviour of a smouldering fuse. It glows/ignites.

7. THIS WAS THE ASSUMPTION (HYPOTHESIS):

If the glowing splint glows/ignites (the independent variable changes as intended), then hydrogen peroxide acts as a reducing agent (the dependent variable will change in this way).

8. WHICH OF THE FOLLOWING CONSTANTS SHOULD BE THE SAME IN ALL EXPERIMENTS? Mark it with ✚! Which(s) did not have to be the same, mark with ➖!

✚ Time elapsed between addition of the reagent and holding the glowing splint; ✚ Volume of Hyperol solution; ➖Volume of test tube; ➖Length of glowing splint

9. LET'S THINK!

Like hydrogen peroxide, hypochlorite is used for disinfection and decolourisation. However, the use of hypochlorite has its own dangers.

"*The Health Toxicology Information Service reported 101 cases of chlorine poisoning last year. The majority of these accidents occur in households, which is why it is important to be careful when using hypochlorite containing and acidic cleaning products.*" - can be read on the website hazipatika.com.

And the blikk.hu website writes the following:

"*Chlorine-based disinfectants and cleaning products used in households do not pose a risk when used alone, as prescribed. The problem arises if you want to increase their effect by simultaneously pouring a descaling agent or other chemical onto the surface to be cleaned. In this case, a chemical reaction produces chlorine gas, which can cause serious symptoms if inhaled*."

The active ingredient in hypochlorite is sodium hypochlorite, which produces hypochlorous acid when used together with hydrochloric acid. The resulting compound forms chlorine gas in an equilibrium reaction with hydrochloric acid.

Write down the two reaction equations mentioned above and then circle the corresponding arrows in the diagram below, recalling what you have learned about the reactions that lead to equilibrium.

NaOCl + HCl = HOCl + NaCl HOCl + HCl ⇌ Cl2 + H2O

↑ ↓

the amount of chlorine gas formed

concentration of hydronium ion

the amount of chlorine gas released into the air

the amount of chlorine gas in the solution

addition of acid

↑ ↓

↑ ↓

↑ ↓

**Student sheet 18: Hydrogen peroxide as a "miracle cure"?**

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

"*Previously used as a throat gargle and known for its antiseptic properties, it has now been found to cleanse blood vessels, oxygenate the blood and can be used to treat cardiovascular diseases; ..., it can be used as an anti-inflammatory, but it is also an effective medicine for oncological diseases.*" – as we can read in József Kovács's book "Hydrogen peroxide, the hidden medicine"[[11]](#footnote-11).

From time to time in recent years, similar fake news about hydrogen peroxide has surfaced, claiming that it can cure almost any disease, even cancer. This would imply that the coronavirus would not have been a problem if we had believed the recent pseudoscientific articles... But hydrogen peroxide is only an external disinfectant, it should not be ingested! It is an interesting substance because, depending on the reactant with which it is in contact, it can act either as an oxidising agent or as a reducing agent in redox reactions. **We will now look at how experiments can show whether hydrogen peroxide acts as an oxidising or reducing agent.**

**Indicate the correct answer by underlining or framing the bold words, or by ~~crossing out~~ the incorrect ones.**

When elemental oxygen gas is produced from hydrogen peroxide by giving off electrons, hydrogen peroxide is **oxidised/reduced** and is therefore an **oxidising/reducing** agent.

Design an experiment to determine, using matches and a wooden splint, whether the hydrogen peroxide in the solution made of Hyperol tablet acts as an oxidizing agent or reducing agent against sodium hypochlorite and the potassium iodide, respectively.

**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, potassium iodide solution, sodium hypochlorite solution, hydrogen peroxide solution made of Hyperol tablet in beaker, 3 test tubes in rack, wooden splint, alcohol burner, matches, watch glass.

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 do in each experiment!

|  |  |  |
| --- | --- | --- |
| 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(s) should not have to be the same, mark with ➖!

[ ]  Time elapsed between addition of the reagent and holding the glowing splint; [ ]  Volume of Hyperol solution; [ ]  Volume of test tube; [ ]  Length of glowing splint

7. THE STEPS OF THE EXPERIMENTS:

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

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**After carrying out the experiments, write down your experience, explanation and conclusion.**

8. OBSERVATION:

(1): ……………………………………………………………………………………………………………………………………………………………………….

(2): ……………………………………………………………………………………………………………………………………………………………………….

(3): ……………………………………………………………………………………………………………………………………………………………………….

9. Explanation:

(1): ……………………………………………………………………………………………………………………………………………………………………….

(2): ……………………………………………………………………………………………………………………………………………………………………….

(3): ……………………………………………………………………………………………………………………………………………………………………….

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

11. LET’S THINK!

Like hydrogen peroxide, hypochlorite is used for disinfection and decolourisation. However, the use of hypochlorite has its own dangers.

"*The Health Toxicology Information Service reported 101 cases of chlorine poisoning last year. The majority of these accidents occur in households, which is why it is important to be careful when using hypochlorite containing and acidic cleaning products.*" - can be read on the website hazipatika.com.

And the blikk.hu website writes the following:

"*Chlorine-based disinfectants and cleaning products used in households do not pose a risk when used alone, as prescribed. The problem arises if you want to increase their effect by simultaneously pouring a descaling agent or other chemical onto the surface to be cleaned. In this case, a chemical reaction produces chlorine gas, which can cause serious symptoms if inhaled*."

The active ingredient in hypochlorite is .........................................................................................., which produces

............................................................ when used together with hydrochloric acid. The resulting compound forms

............................................................ in an equilibrium reaction with hydrochloric acid.

Write down the two reaction equations mentioned above and then circle the corresponding arrows in the diagram below, recalling what you have learned about the reactions that lead to equilibrium.

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

the amount of chlorine gas formed

concentration of hydronium ion

the amount of chlorine gas released into the air

the amount of chlorine gas in the solution

↑↓

↑↓

↑↓

↑↓

addition of acid

**Teacher notes for Student sheet 18: Hydrogen peroxide as a "miracle cure"?**

(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.

"*Previously used as a throat gargle and known for its antiseptic properties, it has now been found to cleanse blood vessels, oxygenate the blood and can be used to treat cardiovascular diseases; ..., it can be used as an anti-inflammatory, but it is also an effective medicine for oncological diseases.*" – as we can read in József Kovács's book "Hydrogen peroxide, the hidden medicine"[[12]](#footnote-12).

From time to time in recent years, similar fake news about hydrogen peroxide has surfaced, claiming that it can cure almost any disease, even cancer. This would imply that the coronavirus would not have been a problem if we had believed the recent pseudoscientific articles... But hydrogen peroxide is only an external disinfectant, it should not be ingested! It is an interesting substance because, depending on the reactant with which it is in contact, it can act either as an oxidising agent or as a reducing agent in redox reactions. **We will now look at how experiments can show whether hydrogen peroxide acts as an oxidising or reducing agent.**

**Indicate the correct answer by underlining or framing the bold words, or by ~~crossing out~~ the incorrect ones.**

When elemental oxygen gas is produced from hydrogen peroxide by giving off electrons, hydrogen peroxide is **oxidised/reduced** and is therefore an **oxidising/reducing** agent.

Design an experiment to determine, using matches and a wooden splint, whether the hydrogen peroxide in the solution made of Hyperol tablet acts as an oxidizing agent or reducing agent against sodium hypochlorite and the potassium iodide, respectively.

**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, potassium iodide solution, sodium hypochlorite solution, hydrogen peroxide solution made of Hyperol tablet in beaker, 3 test tubes in rack, wooden splint, alcohol burner, matches, watch glass.

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 chemical reagent used in the experiment, reacted with hydrogen peroxide.

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

Whether hydrogen peroxide acts as an oxidising or reducing agent.

3. HOW CAN YOU TEST THIS DEPENDENT VARIABLE?

Through the behaviour of a smouldering fuse. It glows/ignites.

4. THIS IS THE ASSUMPTION (HYPOTHESIS): If the glowing splint glows/ignites (the independent variable changes as intended), then hydrogen peroxide acts as a reducing agent (the dependent variable will change in this way).

5. HOW CAN THE INDEPENDENT VARIABLE CHANGE? Plan what to do in each experiment!

|  |  |  |
| --- | --- | --- |
| Experiment 1: (**control** experiment):distilled water + hydrogen peroxide solution made of Hyperol tablet + glowing splint | Experiment 2: e.g. sodium hypochlorite solution + hydrogen peroxide solution made of Hyperol tablet + glowing splint | Experiment 3: e.g. potassium iodide solution + hydrogen peroxide solution made of Hyperol tablet + glowing splint |
| 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(s) should not have to be the same, mark with ➖!

✚ Time elapsed between addition of the reagent and holding the glowing splint; ✚ Volume of Hyperol solution; ➖Volume of test tube; ➖Length of glowing splint

7. THE STEPS OF THE EXPERIMENTS:

(1) We light the alcohol burner, then make a glowing splint.

(2) We add cca. 4 cm3 hydrogen peroxide solution to the distilled water in the test tube, and after about 10 seconds, insert the glowing splint into the test tube.

(3) We repeat the experiment with the other two test tubes of sodium hypochlorite solution and the potassium iodide solution.

**After carrying out the experiments, write down your experience, explanation and conclusion.**

8. OBSERVATION:

(1): No change is observed for distilled water.

(2): In the case of hypochlorite, bubbles are formed, the colourless gas causes the glowing splint to glow/ignite with a crackling sound.

(3): In the case of potassium iodide solution, the solution turns brown, the glowing splint remains unchanged.

9. Explanation:

(1): Distilled water only dilutes the Hyperol solution. No chemical reaction occurs.

(2) Sodium hypochlorite in the hypo reacts with hydrogen peroxide. Oxygen is formed from hydrogen peroxide because sodium hypochlorite is a stronger oxidizing agent than hydrogen peroxide. The oxygen formed causes the glowing splint to glow/ignite. The reaction equation is H2O2 + ClO- = O2 + Cl- + H2O

(3) The iodide ions in the potassium iodide solution are oxidised by hydrogen peroxide to form elemental iodine. The brown colour of iodine is seen. The reaction equation is H2O2 + 2 I- = I2 + 2 OH-

10. CONCLUSION: Hydrogen peroxide acts as a reducing agent for sodium hypochlorite and as an oxidising agent for potassium iodide.

11. LET’S THINK!

Like hydrogen peroxide, hypochlorite is used for disinfection and decolourisation. However, the use of hypochlorite has its own dangers.

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The active ingredient in hypochlorite is sodium hypochlorite, which produces hypochlorous acid when used together with hydrochloric acid. The resulting compound forms chlorine gas in an equilibrium reaction with hydrochloric acid.

Write down the two reaction equations mentioned above and then circle the corresponding arrows in the diagram below, recalling what you have learned about the reactions that lead to equilibrium.

NaOCl + HCl = HOCl + NaCl HOCl + HCl ⇌ Cl2 + H2O

↑ ↓

the amount of chlorine gas formed

concentration of hydronium ion

the amount of chlorine gas released into the air

the amount of chlorine gas in the solution

addition of acid

↑ ↓

↑ ↓

↑ ↓

END OF THE 18th STUDENT SHEETS AND TEACHER NOTES

1. A Mentos candy is dropped into a freshly opened 0,5 litre bottle of Diet Coke standing on a tray. [↑](#footnote-ref-1)
2. A Mentos candy is dropped into a freshly opened 0,5 litre bottle of Diet Coke standing on a tray. [↑](#footnote-ref-2)
3. A Mentos candy is dropped into a freshly opened 0,5 litre bottle of Diet Coke standing on a tray. [↑](#footnote-ref-3)
4. A Mentos candy is dropped into a freshly opened 0,5 litre bottle of Diet Coke standing on a tray. [↑](#footnote-ref-4)
5. A Mentos candy is dropped into a freshly opened 0,5 litre bottle of Diet Coke standing on a tray. [↑](#footnote-ref-5)
6. A Mentos candy is dropped into a freshly opened 0,5 litre bottle of Diet Coke standing on a tray. [↑](#footnote-ref-6)
7. Dr. Kovács József: A hidrogén-peroxid, az eltitkolt gyógyszer, Reménygyógyulás Kft., 2020, ISBN: 9786156156006 [↑](#footnote-ref-7)
8. Dr. Kovács József: A hidrogén-peroxid, az eltitkolt gyógyszer, Reménygyógyulás Kft., 2020, ISBN: 9786156156006 [↑](#footnote-ref-8)
9. Dr. Kovács József: A hidrogén-peroxid, az eltitkolt gyógyszer, Reménygyógyulás Kft., 2020, ISBN: 9786156156006 [↑](#footnote-ref-9)
10. Dr. Kovács József: A hidrogén-peroxid, az eltitkolt gyógyszer, Reménygyógyulás Kft., 2020, ISBN: 9786156156006 [↑](#footnote-ref-10)
11. Dr. Kovács József: A hidrogén-peroxid, az eltitkolt gyógyszer, Reménygyógyulás Kft., 2020, ISBN: 9786156156006 [↑](#footnote-ref-11)
12. Dr. Kovács József: A hidrogén-peroxid, az eltitkolt gyógyszer, Reménygyógyulás Kft., 2020, ISBN: 9786156156006 [↑](#footnote-ref-12)