HYDROGEN

= the first element of the periodic table. Although it is situated in the first group of the periodic table it is not an alkali metal.

Experiment 1: The preparation and the properties of hydrogen

Pour a small amount of dilute hydrochloric acid into a test tube and add there a piece of zinc. Observe the reaction for some time and then place a burning splint on the rim of the test tube.

Conclusion:

Experiment 2: The properties of hydrogen

The hydrogen prepared in Experiment 1 is passed to water containing some detergent. The bubbles made this way rise because hydrogen is .....than air. The bubbles may be ignited with a burning splint.

Conclusion: Hydrogen is .....than air and that's why it was once used in .....

***Experiment 3*:** The reduction of copper(II) oxide by hydrogen

Put a small amount of CuO into a glass tube connected by a rubber hose with the apparatus described in Experiment 1. As the hydrogen released passes through the glass tube, heat it.

Conclusion:

Atom of hydrogen

1. *Describe the three isotopes of hydrogen*

2. *What is the electron configuration of hydrogen?*

3. *What are the most common oxidation numbers of hydrogen?*

4. *What type of bond is there in the hydrogen molecule?*

Occurrence:

Physical properties = *colour, odour, state, density, solubility in water*

Chemical properties

= *oxidising/reducing* agent, reacts with: non-metals: $H_2 + F_2 \rightarrow$ (explosively)

$H_2 + Cl_2 \rightarrow$

$H_2 + O_2 \rightarrow$

$H_2 + N_2 \xrightarrow{Fe,t,p}$

metal oxides: $CuO + H_2 \rightarrow$

alkali metals: $H_2 + Na \rightarrow$

Compounds

hydrides = ... compounds of hydrogen

- **.....**, contain H^- (..... anion)
  = compounds of hydrogen and ....., e.g. CaH_2
  white ..... (state) with *high/low* melting points.
  They react with water to form hydrogen: $NaH + H_2O \rightarrow$ ..... + H_2
  When they undergo electrolysis hydrogen is formed at the *anode/cathode*.

- **covalent**: (with .....), e.g. H_2S

5. *What is the structure and state of covalent hydrides?*

- intersticial (with metals from the centre of the PT) – H_2 molecules fill spaces inside the metal crystal

6. *Which of the substances from the paragraph "Chemical properties" are ionic hydrides and which are covalent hydrides?*

acids, hydroxides, hydrogensalts,
almost all organic substances

Manufacture

7. *Give three ways of manufacturing hydrogen:*
   -
   -
   -

Laboratory preparation

8. *Give three ways of preparing H_2 in the laboratory.*
   -

-
-

Uses:

-
-
-

H_2 is transported and stored in metal cylinders with a ..... stripe.

OXYGEN

= an element of the Group XVI. (VI.A) of the periodic table

Atom of oxygen

1. *Write down the **electron configuration** of oxygen. Use the **box diagram** to show the valence electrons.*

The **electronegativity** of oxygen is ....., it is the second most electronegative element (just after .....)

2. *Estimate **the most common oxidation number** of oxygen in its compounds and give a reason for your answer.*

Other oxidation numbers: ..... – in peroxides O_2^{2-} (H_2O_2)
..... – in oxygen difluoride OF_2

When an oxygen atom combines with atoms of other elements it may achieve a stable noble gas configuration:

- When it *accepts/loses one/two* electrons forming an oxide ion. (CaO)
- When it forms two ..... or one ..... covalent bond.(H_2O, CO_2)
- When it forms one *single/double* bond and *accepts/loses* one electron. (NaOH)

Occurrence

Oxygen is the most abundant element in the Earth's crust. Free oxygen forms .....% of the atmosphere. It is bonded to compounds – minerals, rocks, water organic compounds. It is essential for life.

Properties

Oxygen occurs as two gaseous allotropes, O_2 and O_3.

3. *HW: Use the internet to find the meaning of the word „allotrope".*

Dioxygen (oxygen) O_2

4. *Draw the Lewis (electron) formula of dioxygen molecule:*

By far the more common allotrope, *odour, taste, colour, state*: ……. ……. which condenses to a pale blue liquid at -183°C. Slightly *lighter/heavie*r than air, *soluble/insoluble* in water .

Molecular oxygen *is/is not* very reactive. Its reactions are *endothermic/exothermic*. It acts as a strong ..... agent. The reactions may be very fast, e.g. ..... or very slow, e.g. .....

- combustion – compounds containing C, H, resp. O (hydrocarbons, carbohydrates) are oxidised to…….. and …… A lot of energy is liberated in the form of heat and light.
- respiration – the overall effect is the same as that of burning, but the reaction is much ..... and proceeds at ..... temperature and in the presence of natural catalysts –..... $C_6H_{12}O_6 + 6\ O_2 \rightarrow$ ……
- Oxidation of both metals and non-metals → ……....

5. *Write down the equations for four examples of oxidation of elements by oxygen.*

Preparation

- Thermal decomposition of : .....
- Catalytic decomposition of $H_2O_2 \rightarrow$ .....
- Electrolysis of water, oxygen is made at the *anode/cathode*:.....

Manufacture

- Fractional distillation of liquid air
- Electrolysis of water

Oxygen is naturally made also during photosynthesis: $6\ CO_2 + 6\ H_2O \rightarrow$ .....

Uses

In the steel industry to convert ..... into steel

In ..... and ..... metals (together with acetylene)

In space rockets as an ..... of hydrogen

In medicine .....

Oxygen is transported and stored in metal cylinders with a ..... stripe.

Experiment 1: The preparation of oxygen

Put a spoonful of potassium permanganate into a test tube and heat it. After some time place a glowing splint on the rim of the test tube.

Conclusion:

Experiment 2: Properties of oxygen

Pour hydrogen peroxide solution into two conical flasks. Place a glowing splint in both of them. Then add one spoonful of manganese(IV) oxide to one of them and again place a glowing splint there. Explain your observation.

Conclusion:

Experiment 3: Burning non-metals in oxygen

First put a piece of ignited carbon and then a piece of ignited sulphur into a flask filled with oxygen. Close the flask in order to avoid an escape of any gas. After the reaction add water and prove the presence of an acid using blue litmus paper.

Conclusion:

Trioxygen (.....) O_3 $\quad | \overline{\underline{O}} \leftarrow \overline{O} = \overline{\underline{O}}$

Pungent, pale blue gas. Its presence in the upper atmosphere (25 km) is an important shield against harmful …… from the Sun. It is formed when an oxygen molecule breaks up: *(equation)* ….…… and oxygen atoms made this way combine with oxygen molecules: ….…..……

6. *Explain the term "ozone hole". What is it caused by?*

7. *Explain the term "ground-level ozone" How is it formed? What are its effects on human, plants and animals?*

8. *State another circumstance leading to the formation of ozone.*

Ozone has high oxidising abilities as it decomposes to molecular and atomic (highly reactive) oxygen:..... It is used for the ..... of water and fruits and vegetables.

Oxides = binary compounds of oxygen, oxidation number of oxygen is .....

Classification of oxides:

<u>According to the structure:</u>

- Molecular oxides- simple molecules (usually ..... oxides)
- Atomic oxides – giant covalent structures
- Ionic oxides – ionic crystals (usually oxides of ..... and ..... elements)

9. *Classify CaO, CO_2 and SiO_2 according to their structures.*

<u>According to acid – base properties</u>

- Acidic – usually *metal/non-metal* oxides: either react with water to form .....
  (.....-forming oxides): $SO_2 + H_2O \rightarrow$.....
  or react with hydroxide solutions to make .....: $SiO_2 + NaOH \rightarrow$.....+ .....
- Basic – *metal/non-metal* oxides either react with water to form .....
  (.....-forming oxides) $CaO + H_2O \rightarrow$.....
  or react with ..... to form salt: $MgO + H_2SO_4 \rightarrow$.....+.....
- Amphoteric oxides - react both with acids and bases, (ZnO, Al_2O_3)
- Neutral oxides - react neither with acids nor with bases (N_2O, CO)

10. *Classify MgO, CO_2 and SO_2 according to their acid – base properties.*

<u>WATER</u> H_2O

Occurrence:

Water is the most common compound, it occurs in the three forms of matter:....., ... water, ... Liquid water covers ..... of the Earth's surface, it is a part of living organisms; the human body contains 60% of water. In nature it never occurs in a pure form but it contains dissolved substances which change the properties of water.

Water is also bonded in the crystals of some compounds (.....) in the form of water of crystallization, eg. $CuSO_4 \cdot$ .....H_2O (..... vitriol = ... skalice).

1. *Draw the shape of a water molecule*

Properties:

Isolated molecules of water may be found in water vapour only. The molecules in liquid water are attached to one another through .... This is a reason why water has unique properties: a relatively *high/low* boiling and melting point, *high/low* surface tension, maximum density at .....°C

It is a *polar/non-polar* solvent.

2. *Explain why the water molecule is polar.*

3. *Draw two molecules of water connected by hydrogen bonding.*

Chemical properties

Water is a very stable compound, it may be a product of a reaction or it may act as a reactant or a reacting environment. All important reactions of water will be mentioned later on.

4. *Explain the terms "hygroscopic" and "hydrophobic substances".*
5. *Describe the water cycle in nature.*
6. *Find some information about heavy water.*

Hydrogen peroxide H_2O_2

H_2O_2 is a pale blue liquid with physical properties similar to those of water (m.p. -0.4°C, b.p. 150°C).

7. *Suggest a possible structural formula of H_2O_2.*

The similarity is due to ..... bonding which affects both liquids. It is miscible with water forming a weak ..... Its salts are peroxides (Na_2O_2) and hydrogen peroxides ($NaHO_2$).
In the presence of a catalyst (MnO_2, Pt, blood) or sunlight it decomposes to oxygen and .....

8. *Write down the equation for the decomposition of H_2O_2.*

9. *For what purpose is this decomposition used in everyday life?*

10. *Explain the bleaching and disinfectant properties of H_2O_2 knowing that the principle is the same as in oxidising abilities of ozone.*

Elephant toothpaste: http://www.youtube.com/watch?v=XKli-QGHb40
Bombardier beetle: http://www.youtube.com/watch?v=nFUIEuNeWw4&feature=related

In most reactions it acts as a strong oxidising agent:

11. *Write down the half equation for the reduction of a peroxide ion.*

SOLUTIONS

= homogeneous mixtures consisting of at least two substances. Solution = ... + ...
According to the state of matter: gaseous (air), liquid (NaCl + water), solid (alloys: bronze = Cu + Sn).

Chemical reactions occur in **aqueous solutions** mostly.
When a solute dissolves in a solvent two extreme cases may happen.

1. The particles of the solute **disperse** among the particles of the solvent. The solute may be retrieved from the solution unchanged. E.g. NaCl, O_2, … in water.
2. The solute and the solvent **react** together. The solute is changed. E.g. dissolving metals in acids.

When ionic compounds dissolve in water their ions are ..... (see ionic lattice structures).
Solutions containing freely moving ions conduct electricity. They are called **.....**.
Saturated solution: no more solute dissolves in it (at certain temperature).
Solubility of a solute in a certain solvent may be expressed as: **mass of the solute/ mass of the solvent** or: **amount of the solute/ volume of the solution** (concentration of the solute in the saturated solution)

Quantities expressing the amount of a solute in a solution

1. **Mass percentage *w*** of a solute in a solution**,** it is used mostly for the aqueous solutions of acids, hydroxides and salts

   $w(\mathrm{A}) = \frac{m(\mathrm{A})}{m}$; m(A) … the mass of the solute A, m… the mass of the solution

   1. *A solution was made by dissolving 50 g of NaCl in 200 g of water. Calculate the mass percentage of NaCl in this solution.*

   2. *How many grams of NaCl and what volume of water is needed for the preparation of 600 g of 5% solution?*

2. **Volume percentage *φ*,** it is used for gaseous mixtures or mixtures of miscible liquids.

   $\varphi(\mathrm{A}) = \frac{V(\mathrm{A})}{V}$; V(A) … the volume of the solute, V… the volume of the solution

   3. *30 cm^3 of ethanol was mixed with 70 cm^3 of water. Calculate the percentage by volume of ethanol in this solution.*

   4. *50 cm^3 of a mixture of gases contains: 2.2 cm^3 of CO_2, 16.7 cm^3 of CO and the rest is nitrogen. Express the composition of the mixture using volume percentages.*

3. Concentration *c* (molarity, molar concentration)

$c = \frac{n}{V}$; n … amount of the solute, V … volume of the solution (in dm^3), unit = $mol \cdot dm^{-3}$

5. *Calculate the concentration of 300 cm^3 solution of potassium hydroxide containing 10.5 g KOH.*

6. *What mass of potassium nitrate(III) is contained in 200 cm^3 of 2M solution?*

7. *What mass of soda ash containing 96% of Na_2CO_3 is needed for the preparation of 250 g of 8% solution?*
8. *What mass of 3% solution is made from 45 g of sodium nitrate?*
9. *What is the mass of pure NaOH and water needed for the preparation of 3 litres of 16% solution? (ρ(16% NaOH) =1,175 $g \cdot cm^{-3}$)*
10. *How many percent of pure HNO_3 does nitric acid (ρ = 1.36 $g \cdot cm^{-3}$) contain if it contains 0.8 kg of HNO_3 in 1 dm^3?*
11. *We need to prepare 5 dm^3 of 10% $CuSO_4$ solution. What mass of $CuSO_4 \cdot 5H_2O$ do we need? (ρ = 1.07 $g \cdot cm^{-3}$)*
12. *What is the mass of pure H_2SO_4 contained in 1 dm^3 of 31.4% H_2SO_4 if 1 dm^3 of this acid has the mass of 1230 g?*
13. *The solubility of KNO_3 in water at 40°C is 64 g of KNO_3 in 100 g of water. What is the mass percentage of saturated solution?*
14. *What is the solubility of NaCl in water (per 100 g of water) at 50°C if the saturated solution has w = 27%?*
15. *When all the water is evaporated from 50 g of NaOH solution we get 1g of NaOH. What was the mass percentage?*
16. *What mass of calcium hydroxide is contained in 50 g of 10% solution?*
17. *Calculate the volume of ethanol contained in 50 cm^3 of Label 5 Scotch Whisky (40%).*
18. *Calculate the molar concentration of NaCl if 1000 cm^3 of the solution contains 29.2 g NaCl.*
19. *What is the concentration of 250 ml solution prepared by dissolving 7.3 g NaCl in water?*
20. *Calculate what volume of 0.1 M $FeCl_3$ solution may be prepared from 648.84 g of $FeCl_3$ in water.*
21. *What mass of NaCl do we need for the preparation of 4000 cm^3 of 0.1 M solution?*
22. *What mass of hydrogen chloride is contained in 2 dm^3 of 0.2M solution of HCl?*
23. *What mass of calcium hydroxide is contained in 100 cm^3 of its 0.1M solution?*
24. *What volume of 0.05M $CaCl_2$ solution contains 166.5 g of pure $CaCl_2$?*
25. *100 ml of KOH solution contains 14 g of KOH. What is its molarity?*
26. *Calculate the mass percentage of nitric acid in its 5.62M solution (ρ= 1.18 $g \cdot cm^{-3}$).*
27. *What is the molarity of 10% HCl solution if its density is 1.047 $g \cdot cm^{-3}$.*

28. *Calculate the molarity of 5% sodium carbonate solution if its density is 1.05 g·cm^{-3}.*
29. *What is the concentration of NaCl solution containing 29.22 g of NaCl in 1000 cm^3 of the solution?*
30. *What volume (in ml) of 0.1M $KMnO_4$ solution may be prepared from 55.313 g of $KMnO_4$?*
31. *How many grams of potassium sulphate are needed for the preparation of 1000 ml of 0.25 M solution?*
32. *How many grams of sulphuric acid are contained in 5000 ml of 0.25 M solution?*
33. *Calculate the volume of ammonia (at s.t.p.) needed for the preparation of 1300 ml of 0.2M solution.*

Answers:

1. *20%*
2. *30 g, 570 ml*
3. *30%*
4. *4.4%, 33.4%,62.2%*
5. *0.625 mol·dm^{-3}*
6. *34 g*
7. *20.83 g*
8. *1500 g*
9. *564 g*
10. *58.82%*
11. *836.88 g*
12. *386 g*
13. *39%*
14. *37 g*
15. *2%*
16. *5 g*
17. *20 cm^3*
18. *0.5M*
19. *0.5M*
20. *40 dm^3*
21. *23.38 g*
22. *14.6 g*
23. *0.741 g*
24. *30 dm^3*
25. *2.5 M*
26. *30%*
27. *2.87M*
28. *0.5M*
29. *0.5M*
30. *3500 ml*
31. *43.6 g*
32. *122.6 g*
33. *5.824 dm^3*

Mixing the solutions

There are two basic questions:

- What is the resulting mass percentage of a solution made by mixing two solutions of different mass percentages of a solute?
- How to mix two solutions of different mass percentages of a solute to get a certain value of resulting mass percentage?

Solution 1:	m_1	w_1	$m(A)_1 = m_1 \times w_1$
Solution 2:	m_2	w_2	$m(A)_2 = m_2 \times w_2$
Resulting solution:	$m_1 + m_2$	w	$m(A) = m_1 \times w_1 + m_2 \times w_2$

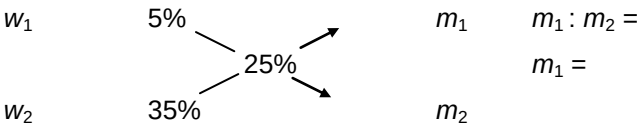
$w = \frac{m_1 \times w_1 + m_2 \times w_2}{m_1 + m_2}$ … **mixing equation**. The mixing equation may be used for solving both types of questions.

1. *200 g of 5% solution of KCl is mixed with 300 g of 10% solution. What is the mass percentage of KCl in the resulting solution?*

2. *What is the mass percentage of a solution made by mixing 33 kg of 10% HCl and 7 kg of 60% HCl?*

However, for solving the questions of the second type it is better to use the so called **cross rule**.

3. *What is the mass of sodium hydroxide solution (w = 5%) needed for the preparation of 25% solution by mixing it with 22 g of 35% solution?*



4. *500 kg of 35.7% HCl was diluted by 8.5% HCl. 30% solution was made. What was the mass of 8.5% HCl added?*

Both the mixing equation and the cross rule may be used also for the cases when a solution is diluted with a pure solvent (*w* = 0%) or when a pure solute (*w* = 100%) is added to a solution.

5. *What mass of HCl (38%) must be diluted with water to get 190 g of 10% solution?*

6. *Use the cross rule to calculate how many parts of water and Na_2SO_4 (by mass) you need to make 15% solution.*

7. *400 g of 92% acid is mixed with 1200 g of 76% acid. What is the resulting mass percentage?*
8. *What is the mass percentage of a solution made by mixing 250 g of 20%, 450 g of 30% and 500 g of 80% solution?*
9. *200 g of 60% solution is diluted with 100 g of water. What is the resulting mass percentage of this solution?*
10. *600 g of 32% HCl must be diluted with 18% HCl so that we get 28% HCl. What mass of 18% HCl must be added?*
11. *15 kg of 65% HNO_3 must be diluted to 2% HNO_3. What mass of water do we need?*
12. *78% and 48% solutions must be mixed in a certain ratio so that we get 66% solution. What is this ratio?*
13. *5% HCl and 2% HCl must be mixed so that we get 300 g of 3% HCl. What masses of 5% and 2% HCl do we need?*

14. *What mass of 5% ethanoic acid may be made from 50 g of 80% ethanoic acid?*
15. *What mass of water is needed for the preparation of 20% solution from 300 g of 40% solution?*
16. *250 g of 36% HCl must be mixed with 5.5% HCl so that we get 25% HCl. What mass of 5.5% HCl do we need?*
17. *What mass of 40% NaOH solution must be diluted with water so that we get 2000 g of 25% NaOH?*
18. *How would you prepare 5 dm^3 of 10% H_2SO_4 (ρ = 1.066 $g \cdot cm^{-3}$) using 92.2% H_2SO_4?*
19. *How many cm^3 of 25% HCl (ρ = 1.127 $g \cdot cm^{-3}$) are needed to make 2 dm^3 of 5% HCl (ρ = 1.024 $g \cdot cm^{-3}$)?*
20. *What mass of water is needed for the preparation of 6% NaOH solution from 300 g of 25% NaOH?*
21. *What volume of water must be added to 150 ml of 37.23% HCl (ρ = 1.19 $g \cdot cm^{-3}$) so that we get 23.82% HCl?*
22. *60% H_2SO_4 and 12% H_2SO_4 are used to make 30% H_2SO_4. In what mass ratio must they be mixed?*
23. *80% HNO_3 must be diluted with 10% HNO_3 so that we get 35%. How many parts of 80% and 10% HNO_3 do we need?*
24. *450 cm^3 of 96% (ρ = 1.841 $g \cdot cm^{-3}$), 110 cm^3 of 65% (ρ = 1.568 $g \cdot cm^{-3}$) and 220 cm^3 of 10% H_2SO_4 (ρ = 1.069 $g \cdot cm^{-3}$) are mixed. What mass of water must be added to the mixture so that the resulting mass percentage is 15%?*
25. *What volume of 36% HCl (ρ = 1.18 $g \cdot cm^{-3}$) and what volume of water is needed for the preparation of 1000 ml of 10% solution (ρ = 1.05 $g \cdot cm^{-3}$) 247.2 ml*

Answers:

1. 8%
2. 18.75%
3. 11 g
4. 132.56 kg
5. 50 g
6. 3 parts K_2SO_4, 17 parts H_2O
7. 80%
8. 48.75%
9. 40%
10. 240 g
11. 472.5 kg
12. 3 parts of 78% and 2 parts of 48%
13. 100 g and 200 g
14. 800 g
15. 300 g
16. 141 g
17. 1250 g of NaOH and 750 g of water
18. 4752 g H_2O + 578 g H_2SO_4
19. 454 cm^3
20. 950 g
21. 100.5 ml
22. 3:5
23. 25 and 45
24. 4944 g
25. 247.2 ml 10% HCl, 708.3 ml H_2O