



Topic4.5.Sulfur and its compounds. Contact method for producing sulfuric acid.

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Outline

- ❖ **Introduction**
- ❖ **Main part**
 - ❖ 1. Sulfur
 - ❖ 2. Hydrogen sulfide and sulfides
 - ❖ 3. Sulfur (IV) oxide, sulfurous acid, sulfites
 - ❖ 4. Sulfur (VI) oxide, sulfuric acid, sulfates
- ❖ **Conclusion**
- ❖ **Literature**



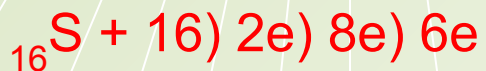
Группа ↓ Период	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra		104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
Лантаноиды				57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
Актиноиды				89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr



1. Sulfur

Chemical element

Sulfur is a chemical element number **16**. It is located in group **VIA**, the third period of the Periodic Table.



The outer layer of the sulfur atom contains six valence electrons. Two electrons are missing to complete the outer layer. Therefore, in compounds with metals and hydrogen, sulfur exhibits an oxidation state of **-2**. When interacting with more electronegative elements (oxygen, halogens), sulfur forms compounds in which its oxidation state is positive (**+4** or **+6**).



1. Sulfur

Chemical element

In the earth's crust, sulfur is found in native form or in the form of minerals and rocks: (pyrite - FeS_2 , zinc blende - ZnS , lead luster - PbS , gypsum - $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, Glauber's salt - $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$).



Native sulfur



Galena



1. Sulfur

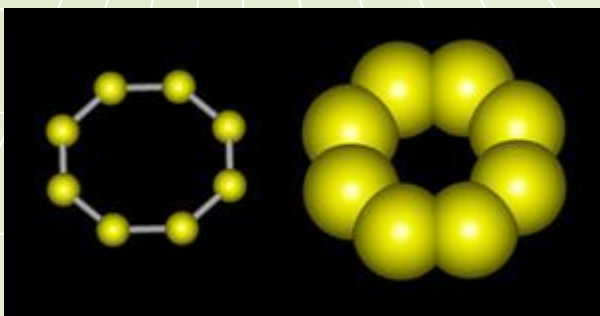
Chemical element

Sulfur belongs to the macronutrients of living organisms. It is found in proteins. Especially a lot of sulfur is in the proteins of hair, horns, wool. It is also included in some vitamins and hormones.

1. Sulfur

Simple substance

Sulfur forms several allotropic modifications. Usually we are dealing with crystalline sulfur, which consists of eight-atomic cyclic molecules.



The molecules form crystals of different structures, and therefore there are allotropic modifications: **rhombic and monoclinic sulfur**. Both modifications are yellow low-melting substances. Their melting points differ slightly (**+112.8 ° C and +119.3 ° C**).



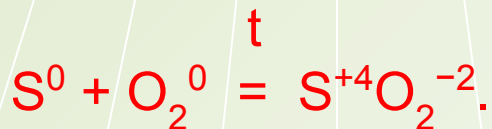
1. Sulfur

Simple substance

When heated, sulfur melts, turns into a light liquid, and then begins to darken and becomes viscous. **Plastic** sulfur is formed, consisting of long linear molecules.

Sulfur **does not dissolve** in water and **is not wetted** by it. Therefore, sulfur powder does not sink in water, despite its higher density (**2.07 g / cm³**). This phenomenon is called **flotation**.

Ignited sulfur reacts with oxygen to form sulfur dioxide. Sulfur in this reaction is a reducing agent.



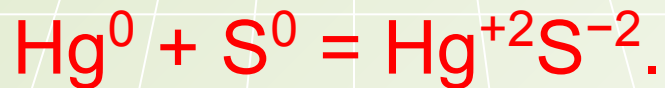


1. Sulfur

Simple substance

Sulfur exhibits oxidizing properties in reactions with metals and hydrogen.

Reacts with active metals and mercury at room temperature:

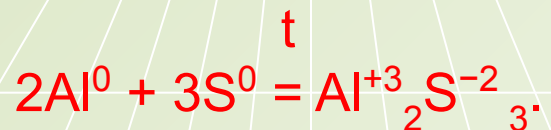




1. Sulfur

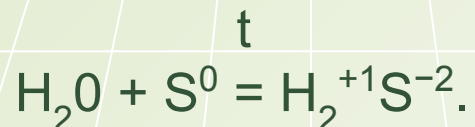
Simple substance

When heated, sulfur reacts with most metals - iron, aluminum, zinc and others, except for gold and platinum.



Sulfides are formed in reactions with metals.

At elevated temperatures, sulfur reacts with hydrogen. Hydrogen sulfide is formed:





1. Sulfur

Simple substance

Sulfur application

- Used in the chemical industry for the production of sulfuric acid;
- finds application in agriculture for the disinfection of premises;
- is part of some ointments;
- used in the production of matches and paper;
- with its help the caoutchouc is turned into rubber;
- is part of explosives.



2. Hydrogen sulfide and sulfides

Hydrogen sulfide

Hydrogen sulfide H_2S is a colorless gas with an unpleasant odor (rotten eggs) under normal conditions, slightly heavier than air. When inhaled, hydrogen sulfide binds to hemoglobin in the blood and interferes with the transfer of oxygen, therefore it is very toxic.

Hydrogen sulfide is formed during the decay of protein products. It is contained in volcanic gases, is constantly released at the bottom of the Black Sea and accumulates in the lower layers of water. It is part of some mineral waters.

Hydrogen sulfide dissolves in water moderately - at room temperature, about **2.5** volumes of hydrogen sulfide dissolve in 1 volume of water.

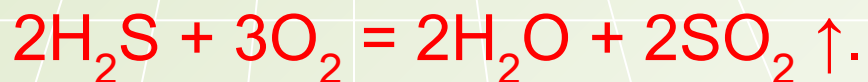
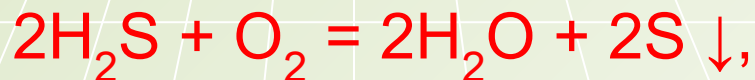


2. Hydrogen sulfide and sulfides

Hydrogen sulfide

In redox reactions, hydrogen sulfide exhibits strong reducing properties due to the sulfur atoms S^{-2} .

It burns easily in oxygen or air to form sulfur or sulfur (IV) oxide:

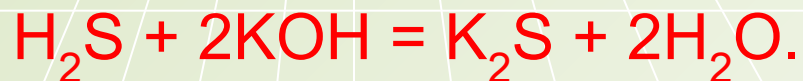




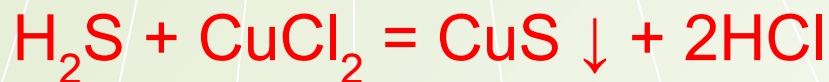
2. Hydrogen sulfide and sulfides

Hydrosulfuric acid

A solution of hydrogen sulfide in water is called **hydrosulfuric acid**. It is a weak dibasic acid. It is characterized by the general properties of acids:



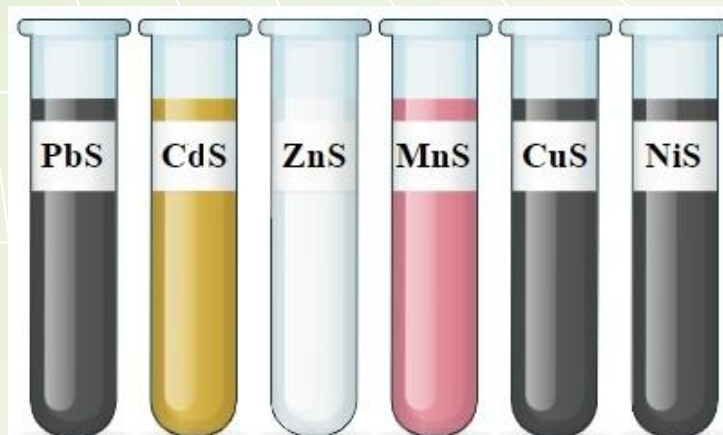
Hydrosulfuric acid enters into a replacement reaction with some salts if insoluble sulfides are formed:



2. Hydrogen sulfide and sulfides

Hydrogen sulfide salts

Medium salts of hydrogen sulfide are called sulfides. Sulfides of active metals and ammonium are soluble in water. Sulfides of other metals do not dissolve in water. Many of them are colored: **NiS**, **CuS**, **PbS** - black, **CdS**, **SnS** - yellow, **MnS** - pink.

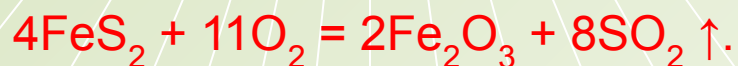




3. Sulfur (IV) oxide, sulfurous acid, sulfites

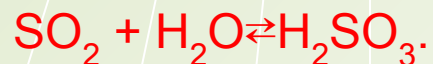
Sulfur (IV) oxide

Sulfur (IV) oxide, is formed during the combustion of sulfur, hydrogen sulfide or the burning of sulfides:



Under normal conditions, it is a colorless gas with a characteristic odor. Poisonous.

Sulfur dioxide dissolves well in water - up to 80 volumes of sulfur dioxide can dissolve in 1 volume of water at 0 ° C, and up to 40 volumes at room temperature. In this case, a reaction occurs with water, and sulfurous acid is formed:

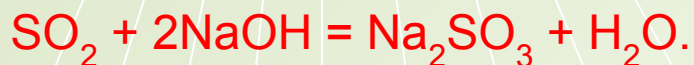




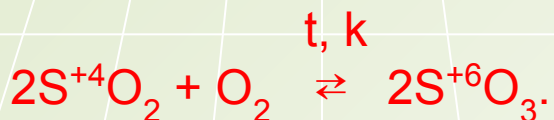
3. Sulfur (IV) oxide, sulfurous acid, sulfites

Sulfur (IV) oxide

Sulfur (IV) oxide also exhibits other properties of acidic oxides: it reacts with alkalis, basic oxides to form salts:



The oxidation state of sulfur in the oxide is **+4**. This is an intermediate value, therefore, in redox reactions, it can be both an oxidizing agent and a reducing agent. Thus, the properties of a reducing agent are manifested in reaction with oxygen:

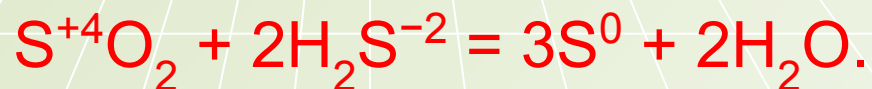




3. Sulfur (IV) oxide, sulfurous acid, sulfites

Sulfur (IV) oxide

Sulfur dioxide exhibits oxidizing properties in reaction with hydrogen sulfide:



Sulfur oxide (IV) is released into the atmosphere when various types of fuel are burned and pollutes it.





Sulfurous acid and its salts

Sulfurous acid H_2SO_3 is an aqueous solution of sulfur (IV) oxide and is not isolated in a free state. It is a weak dibasic acid that forms two rows of salts. Its **normal salts** are called **sulfites** (Na_2SO_3 , CaSO_3), and **acidic salts** are called **hydrosulfites** (NaHSO_3 , $\text{Ca}(\text{HSO}_3)_2$).

Sulfurous acid and its salts, as well as sulfur (IV) oxide, exhibit dual properties in redox reactions - they can be both **oxidizing** and **reducing** agents.



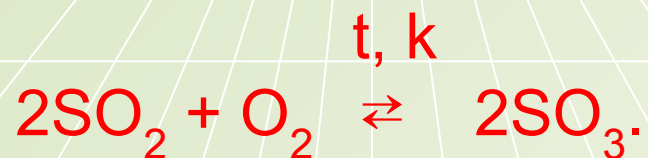
Application

Sulfur dioxide destroys microorganisms, therefore it is used for disinfection of premises and equipment. It is used as a bleaching agent in the production of paper and fabrics. For bleaching, salts are also used: sodium sulfite and sodium hydrosulfite.



Sulfur (VI) oxide

Sulfur oxide (VI) is formed during the catalytic oxidation of sulfur dioxide:



Under normal conditions, it is a **liquid** that reacts with water to form **sulfuric acid**:



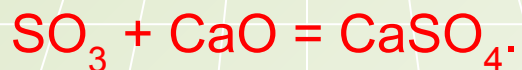
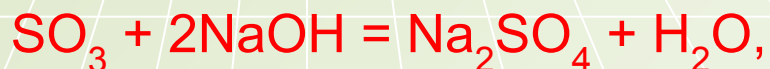
This reaction takes place even with water vapor. Therefore, sulfur oxide (VI) smokes in air.



Sulfur (VI) oxide

A feature of sulfur (VI) oxide is its ability to dissolve in concentrated sulfuric acid to form **oleum**.

Sulfur (VI) oxide is a typical **acidic oxide**. It reacts with bases and basic oxides to form salts:



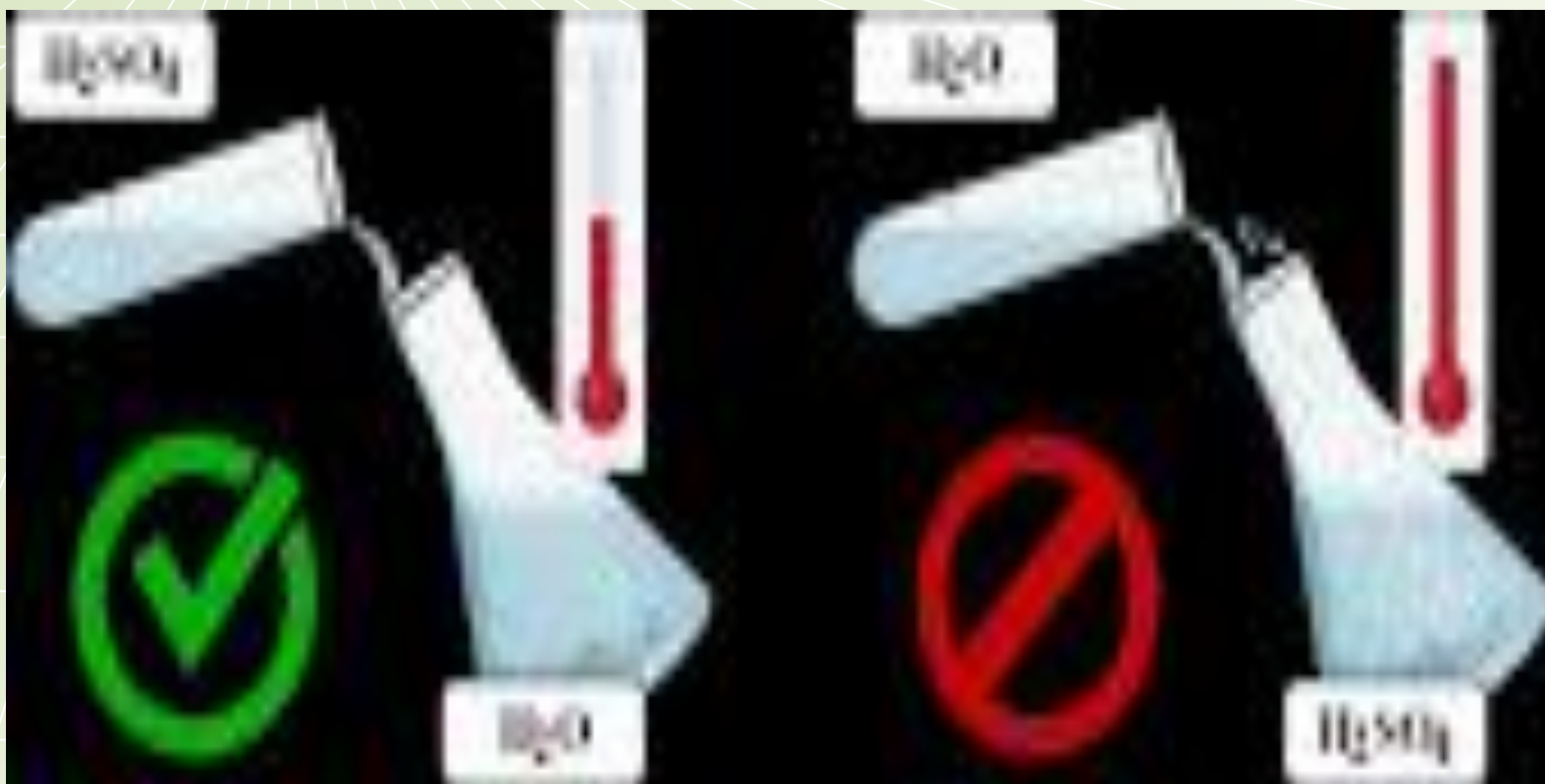
The oxidation state of sulfur in this oxide is +6. This is the maximum value for sulfur, so in redox reactions it can only be an **oxidizing agent**.



Sulfuric acid

Sulfuric acid H_2SO_4 is the most important sulfur compound. Pure sulfuric acid is a colorless, viscous, oily liquid that is almost twice as heavy as water.

Sulfuric acid is infinitely miscible with water. Dissolution of sulfuric acid is accompanied by strong heating of the solution, and splashing may occur. Therefore, sulfuric acid is carefully dissolved: a thin stream of **acid is poured into water** with constant stirring.



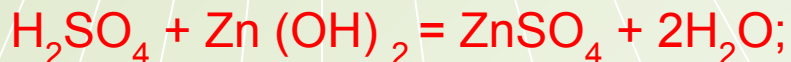
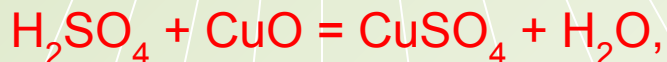


Sulfuric acid

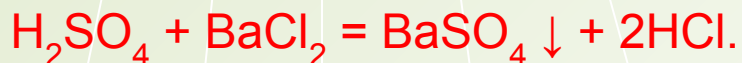
Sulfuric acid is very hygroscopic and is used to dry various substances. The chemical properties of sulfuric acid depend on its concentration.

Sulfuric acid of any concentration reacts:

-with basic and amphoteric oxides and hydroxides with the formation of salt and water:



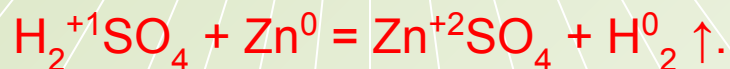
-with salts, if a gas or an insoluble substance is formed:



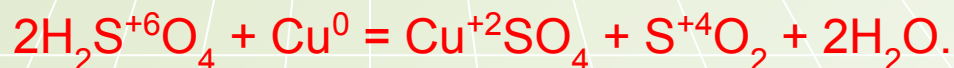


Sulfuric acid

Diluted acid reacts only with metals, located in the row of activity before hydrogen. The reaction produces sulfates and hydrogen is released. **Hydrogen atoms exhibit oxidizing properties** in this case:



The concentrated acid reacts with all metals except gold and platinum, due to the **strong oxidizing properties of the sulfur atom**:



In reactions with active metals, the reaction products can be sulfur dioxide, hydrogen sulfide or sulfur.

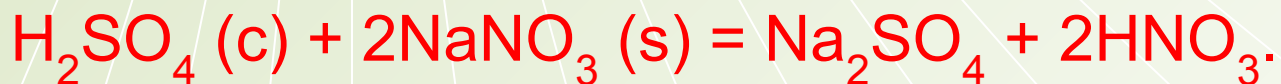


Sulfuric acid

Pay attention!

At low temperatures, iron and aluminum passivates and does not react with them.

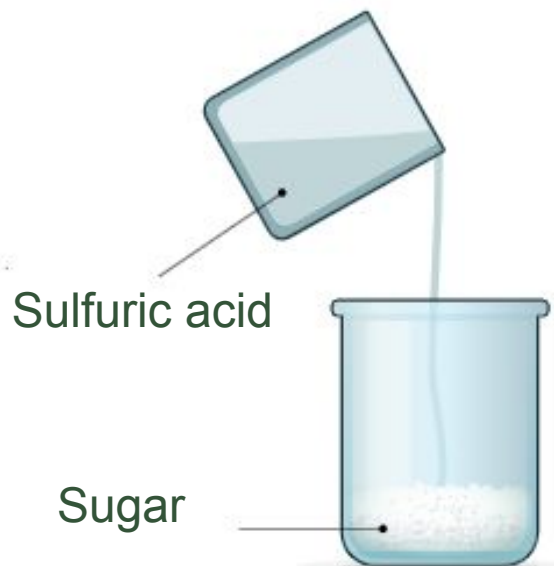
With solid salts of other acids:



With many organic substances (carbonization of sugar, paper, wood, etc. occurs, since water is taken away):



Time : 0s 0c



Time: 15s 15c



Time: 60s 60c

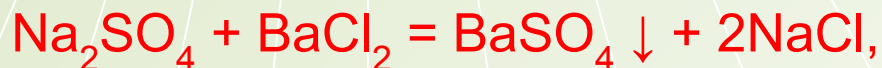




Sulfuric acid salts

Sulfuric acid forms two series of salts. Medium salts are called **sulfates** (Na_2SO_4 , CaSO_4), and acidic salts are called **hydrosulfates** (NaHSO_4 , $\text{Ca}(\text{HSO}_4)_2$).

A **qualitative reaction** to sulfuric acid and its salts is the reaction with soluble barium salts - a white precipitate of barium sulfate precipitates:





Application

Sulfuric acid is one of the most important chemicals. It is used:

to obtain other acids;

for the production of mineral fertilizers;

for cleaning petroleum products;

in lead-acid batteries;

in the production of detergents, dyes, medicines.

Sulfuric acid salts are also used. Copper sulfate

$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ is used to combat plant diseases, gypsum

$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ is used in construction, barium sulfate

BaSO_4 is used in medicine.

The contact method of production of the sulfuric acid

<https://www.youtube.com/watch?v=Bu3ns9li80M>



Questions for selfcontrol:

1. Note the name of the substance with the composition CaS :

- A) calcium hydrosulfite
- B) calcium hydrogen sulfate
- C) calcium sulfate
- D) calcium sulfide

2. Sulfur (IV) oxide in redox reactions due to sulfur atoms

- A) is a reducing agent
- B) is an oxidizing agent
- C) can be both an oxidizing agent and a reducing agent

3. Pure sulfuric acid is an oily, colorless liquid.

- A) False
- B) True

4. Diluted sulfuric acid does not react with copper.

- A) False
- B) True



5. Choose the characteristic of sulfur:

- A) in thick layers is purple
- B) not wetted with water
- C) obtained in the laboratory from sulfuric acid
- D) good solvent

6. Sulfur (VI) oxide has the following properties:

- A) blue
- B) sulfur oxidation state +4
- C) only oxidizing properties
- D) formation of salt and water when interacting with alkalis

7. Sulfur (IV) oxide has the following properties:

- A) amphoteric properties
- B) gaseous state under normal conditions
- C) formation of sulfites in reactions with alkalis
- D) formation of a strong acid when dissolved in water



8. Diluted sulfuric acid differs from concentrated sulfuric acid:

- A) By the ability to displace all other acids from solid salts
- B) By the formation of sulfates in reactions with metal hydroxides
- C) By the ability to react with barium salts
- D) By the evolution of hydrogen when interacting with iron

9. Diluted sulfuric acid differs from concentrated sulfuric acid:

- A) By the oxidizing properties due to the hydrogen atom
- B) By the ability to react with silver
- C) By the reaction with amphoteric hydroxides
- D) By the ability to react with carbonates

10. Only diluted sulfuric acid reacts with all substances of the series:

- A) $\text{Be}(\text{OH})_2$, KCl , MgO
- B) Ag_2O , CuOH , Na_2CO_3
- C) Fe , BaCO_3 , CuO
- D) KCl , Ag , NO



11. Only concentrated sulfuric acid reacts with all substances of the series:

A) CO_2 , CO , NO

B) Fe_2O_3 , FeO , Fe

C) Hg , $\text{Mg}(\text{OH})_2$, ZnO

D) CaO , $\text{Cu}(\text{OH})_2$, CuO

12. Establish a correspondence between the formula of a substance and its characteristics.

1 - SO_2 , 2 - SO_3 , 3 - H_2S , 4 - H_2SO_4 ; (conc.)

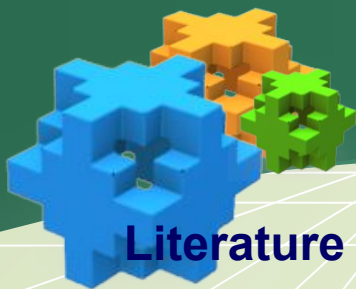
a - is formed during the decay of proteins;

b - can react with copper;

c - in the presence of a catalyst, it is oxidized with oxygen;

d - formed during the catalytic oxidation of sulfur dioxide;

d - does not dissolve in water.



Literature

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7. Жакирова Н., Жандосова И. и др Химия.Электронный учебник.11-класс.2016 Национальный центр информатизации
8. Электронные ресурсы с www.bilimland.kz

Do you have any questions?

