

# Worksheet: Uses of Sulfuric Acid



In this worksheet, we will practice describing the uses of sulfuric acid, balancing reaction equations, and calculating the quantities of acid involved.

**Q1:** Sulfuric acid can be used to identify halide ions in aqueous solutions.



Chloride salts react with sulfuric acid to form hydrogen chloride and other products. Give a balanced chemical equation for the reaction of excess sodium chloride with sulfuric acid.



Bromide salts react with sulfuric acid to form sulfur dioxide, red-brown bromine vapor, water, and a sulfate salt. Give a balanced chemical equation for the reaction of sodium bromide with excess sulfuric acid.



Iodide salts react with sulfuric acid and water to form hydrogen sulfide, purple iodine vapor, and a sulfate salt. Give a balanced chemical equation for the reaction of sodium iodide with excess sulfuric acid.

**Q2:** Many reactions involving sulfuric acid produce soluble sulfate salts. Salts of certain alkaline earth metals can be used to test for the presence of these soluble salts and to differentiate these compounds from hydroxides and carbonates.



Which alkaline earth metal forms the most suitable salts for the identification of soluble sulfates?



When a suitable alkaline earth metal salt is added to a solution, what observation confirms the presence of soluble sulfates?

**Q3:** Sulfuric acid reacts with alkaline earth metals to form sulfate salts.



What are the other products of these reactions?



What is the formula of the salt produced when calcium metal reacts with sulfuric acid?



What is the heaviest alkaline earth metal capable of forming a sulfate salt that is highly soluble in pure water?



For which alkaline earth metal do the sulfate and hydroxide salts display the most similar water solubilities?

**Q4:** Sulfate salts can be produced by reacting oxide compounds with sulfuric acid.



What are the other products of these reactions?



What is the formula of the salt produced when potassium oxide reacts with sulfuric acid?



Which element in Period 3 of the periodic table forms a solid oxide that is unreactive with aqueous sulfuric acid?



Which element in Period 3 of the periodic table forms the basic oxide with the highest reactivity toward sulfuric acid?

**Q5:** Aluminum sulfate can be produced by the reaction of aluminum with sulfuric acid. The reaction of this salt with sodium hydrogen carbonate ( $\text{NaHCO}_3$ ) is used to generate carbon dioxide in fire extinguisher foams. The other products of this reaction are sodium sulfate and an aluminum salt containing no carbon atoms.



Give a balanced chemical equation for the formation of aluminum sulfate from aluminum and sulfuric acid.



What is the formula of the aluminum salt produced by the reaction of aluminum sulfate with sodium hydrogen carbonate?



A fire extinguisher contains 23.0 g of aluminum sulfate. What mass of sodium hydrogen carbonate is needed for the aluminum sulfate to react completely?



A fire extinguisher contains 50.0 g of aluminum sulfate and 65.0 g of sodium hydrogen carbonate. When the compounds in the extinguisher react, every mole of carbon dioxide produced increases the volume of foam by 24.0 L. Calculate the maximum volume of foam that the fire extinguisher can produce.

**Q6:**

In dilute solutions, sulfuric acid completely dissociates. Calculate, to 3 significant figures, the pH of a 600 cm<sup>3</sup> solution containing 2.20 g of pure sulfuric acid.

**Q7:** An aqueous sulfuric acid solution has a volume of 840 cm<sup>3</sup> and a pH of 0.850.



Calculate the molar concentration of sulfuric acid in the solution to 3 significant figures.



Calculate, to 3 significant figures, the mass of potassium hydroxide that must be added to neutralize this solution.



A 25.0 cm<sup>3</sup> sample of this solution is titrated against 0.190 M aqueous sodium hydroxide. Calculate, to 3 significant figures, the volume of titrant needed to reach the end point of the titration.

**Q8:** Chlorine dioxide ( $\text{ClO}_2$ ) is a yellow-green gas used in water treatment. The gas can be generated by the reaction of sodium chlorite ( $\text{NaClO}_2$ ) with sulfuric acid. Chloric acid ( $\text{HClO}_3$ ), hydrochloric acid, sodium sulfate, and water are produced as by-products:



This reaction alters the pH of the solution but does not significantly alter the total volume. It may be assumed that the sulfuric, chloric, and hydrochloric acids remain in solution and are the only acidic compounds involved in the reaction.

▶ A sulfuric acid solution with a pH of 1.33 is reacted with excess sodium chlorite. Calculate the pH of the solution at the end of the reaction.

▶ Sodium chlorite is reacted with 2.50 L of aqueous sulfuric acid. The pH of the acid before the reaction is 1.20. At the end of the reaction, the pH is 1.38. Calculate, to 3 significant figures, the mass of chlorine dioxide produced.

▶ A batch of chlorine dioxide is produced by reacting 18.0 kg of sodium chlorite with aqueous sulfuric acid. The pH of the acid is 0.190. Calculate, to 3 significant figures, the minimum volume of acid needed.

**Q9:** Sulfuric acid is used directly and indirectly in the manufacture of many organic compounds, including the pH indicator methyl orange ( $\text{C}_{14}\text{H}_{14}\text{N}_3\text{NaO}_3\text{S}$ ). One molecule of sulfuric acid is used in the production of one molecule of methyl orange.

▶ Calculate the relative molecular mass of methyl orange to the nearest atomic mass unit.

▶ Calculate the mass of methyl orange that can be produced using 5.00 kg of sulfuric acid.

▶ A 210 g sample of methyl orange is produced using 84.5 g of sulfuric acid. Calculate the percentage yield.

**Q10:** Sulfuric acid is used directly and indirectly in the manufacture of many organic compounds, including the pH indicator bromothymol blue ( $C_{27}H_{28}O_5SBr_2$ ). One molecule of sulfuric acid is used in the production of one molecule of bromothymol blue.

▶ Calculate the relative formula mass of bromothymol blue to the nearest atomic mass unit.

▶ Calculate the mass of bromothymol blue that can be produced from 50.0 g of sulfuric acid.

▶ A 4.80 kg sample of bromothymol blue is produced using 1.23 kg of sulfuric acid. Calculate the percentage yield.

**Q11:**

Before rolled steel sheets are coated with other materials, surface ferric oxide ( $Fe_2O_3$ ) must be removed. A common method is to react the ferric oxide with sulfuric acid to produce a soluble salt. Write a balanced chemical equation for this reaction.

**Q12:** Titanium dioxide ( $TiO_2$ ) is an insoluble solid used as a white pigment. In the most common method of titanium dioxide production, the titanium ore ilmenite ( $FeTiO_3$ ) reacts with sulfuric acid to form titanium oxysulfate ( $TiOSO_4$ ), ferrous sulfate ( $FeSO_4$ ), and another compound. Titanium oxysulfate is converted to titanium dioxide via a second reaction.

▶ Write a balanced chemical reaction for the production of titanium oxysulfate from ilmenite.

▶  
What is the main reason for removing ferrous sulfate from titanium oxysulfate before it is converted to a titanium dioxide pigment?

- A Ferrous sulfate would react with the titanium dioxide.
- B Ferrous sulfate is highly toxic.
- C Ferrous sulfate decomposes to produce a toxic gas.
- D Ferrous sulfate would react with the reagent of the final reaction.
- E Ferrous sulfate is highly colored.

▶  
One molecule of titanium oxysulfate reacts with one molecule of X to form titanium dioxide and one molecule of sulfuric acid. There are no other reactants or products. Identify the molecule X.

**Q13:**

What is the most common method used to manufacture sulfuric acid?

**Q14:** One of the most important applications of sulfuric acid is the preparation of phosphoric acid ( $\text{H}_3\text{PO}_4$ ) from minerals, such as apatite ( $\text{Ca}_5(\text{PO}_4)_3\text{OH}$ ).

▶  
Give a balanced chemical equation for the formation of phosphoric acid and water from sulfuric acid and apatite.



The majority of synthetically manufactured phosphoric acid is consumed in the manufacture of which type of product?

- A Batteries
- B Fertilizers
- C Steel
- D Fuels
- E Medicines

**Q15:** Ores containing cupric oxide ( $\text{CuO}$ ) are commonly reacted with sulfuric acid to produce a copper-containing material that is more easily processed. This process is known as sulfuric acid leaching.



Write a balanced chemical equation for the reaction of cupric oxide with sulfuric acid.



What is the name of the copper-containing compound produced when cupric oxide reacts with sulfuric acid?

▶  
What is the main reason for sulfuric acid leaching of cupric oxide ores?

- A The product of the reaction is less toxic than cupric oxide.
- B The product of the reaction has a lower melting point than cupric oxide.
- C The product of the reaction is less stable than cupric oxide so it can be electrolyzed more easily.
- D The product of the reaction is more soluble than cupric oxide.
- E The product of the reaction forms smaller crystals than cupric oxide so it can be ground up more easily.

▶  
To obtain metallic copper, the product of sulfuric acid leaching is reacted with another elemental metal. By considering their relative costs and reactivities, determine which of the following metals is most suitable for use in this reaction.

- A Silver
- B Lead
- C Sodium
- D Iron
- E Aluminum

**Q16:** Pyrite ( $\text{FeS}_2$ ) is a commonly mined ore. Bacteria can convert all of the sulfur in pyrite to sulfuric acid using oxygen and water.



Bacteria initially convert pyrite to the soluble salt ferrous sulfate ( $\text{FeSO}_4$ ) using oxygen and water. Write a balanced chemical equation for this reaction.



At low pH, bacteria convert pyrite to the insoluble salt ferric hydroxide ( $\text{Fe}(\text{OH})_3$ ) using oxygen and water. Write a balanced chemical equation for this reaction.



Mining accelerates the conversion of pyrite to sulfuric acid by exposing the rock to air and water. What is the main disadvantage of this process?

- A The reaction destabilizes the rock, making mining more dangerous.
- B The reaction produces compounds that are damaging to aquatic organisms.
- C The reaction removes oxygen from lakes and streams, damaging aquatic organisms.
- D The reaction produces compounds that are damaging to mining equipment.
- E The reaction reduces the quantity of iron ore available for mining.



Calculate the maximum mass of sulfuric acid that can be produced by bacteria from 150 kg of pure pyrite.

Q17:

Which symbol represents the main hazard associated with pure sulfuric acid?

A



B



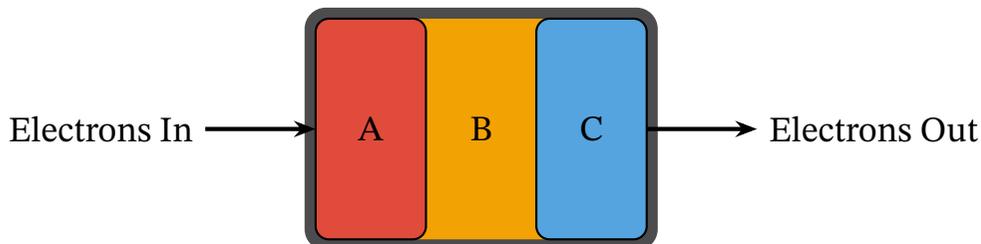
C



D



**Q18:** Lead-acid batteries, the oldest type of rechargeable batteries, are used in many vehicles and large-scale energy storage applications. The main components of the batteries are lead dioxide ( $\text{PbO}_2$ ), elemental lead, and aqueous sulfuric acid. Electricity is produced as the lead dioxide reacts with sulfuric acid to produce lead sulfate ( $\text{PbSO}_4$ ). A schematic of a charged lead-acid battery is shown.



▶ Identify the components A, B, and C in the schematic diagram.

▶ Give a balanced chemical equation for the overall reaction responsible for electricity production.

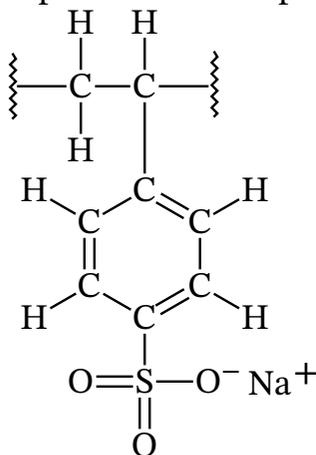
▶ What term best describes the function of aqueous sulfuric acid in this battery?

▶ What term best describes the function of lead dioxide in this battery?



▶ Calculate the mass of SDS that can be produced using 110.0 kg of sulfuric acid.

**Q20:** Reagents derived from sulfuric acid are used in the production of organic sulfonates. One example of an organic sulfonate is the polymer sodium polystyrene sulfonate, an ion-binding material with medical applications. The repeat unit of the polymer has the shown structural formula.



▶ Calculate the relative formula mass of the sodium polystyrene sulfonate repeat unit to the nearest atomic mass unit.

▶ Calculate the mass of sulfuric acid needed to produce 290 g of sodium polystyrene sulfonate.

▶ A 32.0 kg batch of sodium polystyrene sulfonate was prepared using 12.6 L of pure sulfuric acid. The density of pure sulfuric acid is 1.84 g/cm<sup>3</sup>. Calculate the percentage yield.