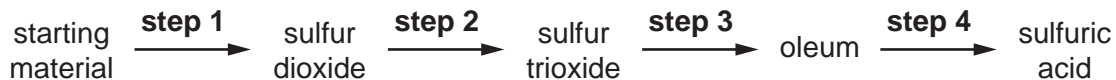


1 Sulfuric acid is produced by the Contact process. The steps of the Contact process are shown.



(a) Sulfur is a common starting material for the Contact process.

Name a source of sulfur.

..... [1]

(b) Describe **step 2**, giving reaction conditions and a chemical equation. Reference to reaction rate and yield is not required.

.....
.....
.....
.....
.....
.....
.....
.....
..... [5]

(c) **Step 3** involves adding sulfur trioxide to concentrated sulfuric acid to form oleum.

Complete the chemical equation for this reaction.



[1]

(d) Dilute sulfuric acid is a typical acid.

A student adds excess dilute sulfuric acid to a sample of solid copper(II) carbonate in a test-tube.

(i) Give **three** observations the student would make.

.....
.....
..... [2]

(ii) Give the **names** of all products formed.

.....
..... [1]

(e) Concentrated sulfuric acid has different properties to dilute sulfuric acid.

When concentrated sulfuric acid is added to glucose, $C_6H_{12}O_6$, steam is given off and a black solid is formed.

(i) Name the black solid.

..... [1]

(ii) What type of reaction has occurred?

..... [1]

[Total: 12]

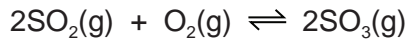
2 Sulfuric acid is made by the Contact process.

(a) Sulfur is burned by spraying droplets of molten sulfur into air.

Suggest and explain an advantage of using this method.

.....
..... [2]

(b) The following equation represents the equilibrium in the Contact process.



Oxygen is supplied from the air.

The composition of the reaction mixture is 1 volume of sulfur dioxide to 1 volume of oxygen.

What volume of air contains 1 dm³ of oxygen?

..... dm³ [1]

(c) Sulfur dioxide is more expensive than air.

What is the advantage of using an excess of air?

.....
..... [2]

(d) The forward reaction is exothermic. The reaction is usually carried out at a temperature between 400 and 450 °C.

(i) What is the effect on the position of equilibrium of using a temperature above 450 °C?
Explain your answer.

.....
.....
..... [2]

(ii) What is the effect on the rate of using a temperature below 400 °C?
Explain your answer.

.....
.....
..... [3]

(e) A low pressure, 2 atmospheres, is used. At equilibrium, about 98% SO₃ is present.

(i) What is the effect on the position of equilibrium of using a higher pressure?

..... [1]

(ii) Explain why a higher pressure is **not** used.

..... [1]

(f) Name the catalyst used in the Contact process.

..... [1]

(g) Describe how concentrated sulfuric acid is made from sulfur trioxide.

.....
.....
.....
..... [2]

[Total: 15]

3 The main use of sulfur dioxide is the manufacture of sulfuric acid.

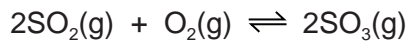
(a) State **two** other uses of sulfur dioxide.

.....
..... [2]

(b) One source of sulfur dioxide is burning sulfur in air.
Describe how sulfur dioxide can be made from the ore zinc sulfide.

.....
..... [2]

(c) The Contact process changes sulfur dioxide into sulfur trioxide.



the forward reaction is exothermic

temperature 400 to 450 °C

low pressure 1 to 10 atmospheres

catalyst vanadium(V) oxide

(i) What is the formula of vanadium(V) oxide?

..... [1]

(ii) Vanadium(V) oxide is an efficient catalyst at any temperature in the range 400 to 450 °C.
Scientists are looking for an alternative catalyst which is efficient at 300 °C.
What would be the advantage of using a lower temperature?

.....
.....
..... [2]

(iii) The process does not use a high pressure because of the extra expense.
Suggest **two** advantages of using a high pressure?
Explain your suggestions.

.....
.....
.....
.....
..... [4]

- (d) Sulfuric acid is made by dissolving sulfur trioxide in concentrated sulfuric acid to form oleum. Water is reacted with oleum to form more sulfuric acid. Why is sulfur trioxide not reacted directly with water?

..... [1]

[Total: 12]

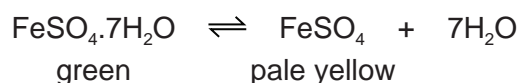
4 Sulfuric acid is an important acid, both in the laboratory and in industry. Sulfuric acid is manufactured in the Contact Process. Originally, it was made by heating metal sulfates and by burning a mixture of sulfur and potassium nitrate.

(a) Give a major use of sulfuric acid.

..... [1]

(b) A group of naturally occurring minerals have the formula of the type $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$ where x is 1, 4, 5, 6 or 7. The most common of these minerals is iron(II) sulfate-7-water.

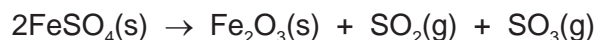
(i) When this mineral is heated gently it dehydrates.



Describe how you could show that this reaction is reversible.

.....
.....
..... [2]

(ii) When the iron(II) sulfate is heated strongly, further decomposition occurs.



The gases formed in this reaction react with water and oxygen to form sulfuric acid. Explain how the sulfuric acid is formed.

.....
..... [2]

(iii) A mineral of the type $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$ contains 37.2% of water. Complete the calculation to determine x.

mass of one mole of H_2O = 18 g

mass of water in 100 g of $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$ = 37.2 g

number of moles of H_2O in 100 g of $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$ =

mass of FeSO_4 in 100 g of $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$ = g

mass of one mole of FeSO_4 = 152 g

number of moles of FeSO_4 in 100 g of $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$ =

x =

[4]

(c) When a mixture of sulfur and potassium nitrate is burned and the products are dissolved in water, sulfuric acid is formed.

(i) The sulfuric acid formed by this method is not pure. It contains another acid.
Deduce the identity of this acid.

..... [1]

(ii) The heat causes some of the potassium nitrate to decompose.
Write the equation for the action of heat on potassium nitrate.

..... [2]

[Total: 12]

5 Sulfuric acid is a strong acid. Hexanesulfonic acid is also a strong acid. It has similar properties to sulfuric acid.

(a) Sulfonic acids are made from alkanes and oleum, $H_2S_2O_7$.



(i) Describe how oleum is made from sulfur by the Contact process. Give equations and reaction conditions.

.....

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.....

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.....

.....

..... [6]

(ii) How is concentrated sulfuric acid made from oleum?

..... [1]

(b) The formula of the hexanesulfonate ion is $C_6H_{13}SO_3^-$.

The formula of the barium ion is Ba^{2+} . What is the formula of barium hexanesulfonate?

..... [1]

(c) Complete the following equations.

(i) magnesium + hexanesulfonic acid \rightarrow + [1]

(ii) calcium oxide + hexanesulfonic acid \rightarrow + [1]

(iii) $C_6H_{13}SO_3H$ + Na_2CO_3 \rightarrow + + [2]

(d) (Sulfuric acid is a strong acid.
You are given aqueous sulfuric acid, concentration 0.1 mol/dm^3 , and aqueous hexanesulfonic acid, concentration 0.2 mol/dm^3 . Describe how you could show that hexanesulfonic acid is also a strong acid.

.....
..... [2]

(ii) Deduce why, for a fair comparison, the two acid solutions must have different concentrations.

.....
..... [1]

(iii) Explain the terms *strong acid* and *weak acid*.

.....
.....
..... [2]

[Total: 17]