

1 The food additive E220 is sulfur dioxide. It is a preservative for a variety of foods and drinks.

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

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

(b) How is sulfur dioxide manufactured?

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

(c) Sulfur dioxide is a reductant (reducing agent). Describe what you would see when aqueous sulfur dioxide is added to acidified potassium manganate(VII).

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

(d) Sulfur dioxide can also be made by the reaction between a sulfite and an acid.



Excess hydrochloric acid was added to 3.15 g of sodium sulfite. Calculate the maximum volume, measured at r.t.p., of sulfur dioxide which could be formed.
The mass of one mole of Na_2SO_3 is 126 g.

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

[Total: 9]

2 A major ore of zinc is zinc blende, ZnS. A by-product of the extraction of zinc from this ore is sulfur dioxide which is used to make sulfuric acid.

(a) (i) Zinc blende is heated in air. Zinc oxide and sulfur dioxide are formed. Write the balanced equation for this reaction.

..... [2]

(ii) Zinc oxide is reduced to zinc by heating with carbon. Name **two** other reagents which could reduce zinc oxide.

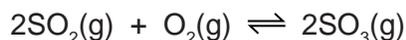
..... [2]

(iii) The zinc obtained is impure. It is a mixture of metals. Explain **how** fractional distillation could separate this mixture.

zinc bp = 908 °C, cadmium bp = 765 °C, lead bp = 1751 °C

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

(b) Sulfur dioxide is used to make sulfur trioxide in the Contact Process.



The forward reaction is exothermic. The conditions used are:

temperature: 450 °C
pressure: 2 atmospheres
catalyst: vanadium(V) oxide

Explain, mentioning both position of equilibrium and rate, why these conditions give the most economic yield.

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

[Total: 10]

3 Sulfur is needed for the production of sulfuric acid. Two of the major sources of sulfur

- underground deposits of the element sulfur,
- sulfur compounds from natural gas and petroleum.

(a) Explain why sulfur and its compounds are removed from these fuels before they are burned.

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

(b) Sulfur dioxide is made by spraying molten sulfur into air. The sulfur ignites and sulfur dioxide is formed.

(i) Suggest why molten sulfur is used in the form of a fine spray.

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

(ii) Explain why traces of sulfur dioxide act as a preservative in fruit juices.

..... [1]

(iii) State another use of sulfur dioxide.

..... [1]

(c) Describe how sulfur dioxide is changed into sulfur trioxide. Give the reaction conditions and an equation.

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

(d) Complete the following equations for the formation of sulfuric acid from sulfur trioxide.



[Total: 12]

4 The major use of sulfur dioxide is to manufacture sulfuric acid.

(a) (i) Another use of sulfur dioxide is as the food additive E220.
How does it preserve food?

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

(ii) Why is sulfur dioxide used in the manufacture of wood pulp?

..... [1]

(iii) How is sulfur dioxide manufactured?

..... [1]

(b) Complete the following description of the manufacture of sulfuric acid.

Sulfur dioxide reacts with to form sulfur trioxide.

The above reaction is catalysed by

The optimum temperature for this reaction is °C.

Sulfur trioxide needs to react with to form sulfuric acid. [4]

(c) (i) Define the term *acid*.

..... [1]

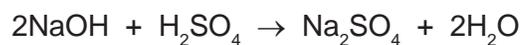
(ii) Sulfuric acid is a strong acid. Ethanedioic acid is a weak acid.

Given solutions of both acids, how could you show that sulfuric acid is a strong acid and ethanedioic acid is a weak acid?

method
..... [1]

result for each acid
..... [1]

- (d) 20.0 cm³ of sulfuric acid, concentration 0.30 mol/dm³, was added to 40 cm³ of sodium hydroxide, concentration 0.20 mol/dm³.



(i) How many moles of H₂SO₄ were added? [1]

(ii) How many moles of NaOH were used? [1]

(iii) Which reagent is in excess? Give a reason for your choice.

reagent in excess [1]

reason

..... [1]

(iv) Is the pH of the final mixture less than 7, equal to 7 or more than 7?

..... [1]

[Total: 15]

5 (a) Sulfuric acid is made by the Contact process.



This is carried out in the presence of a catalyst at 450 °C and 2 atmospheres pressure.

(i) How is the sulfur dioxide made?

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

(ii) Give another use of sulfur dioxide.

..... [1]

(iii) Name the catalyst used.

..... [1]

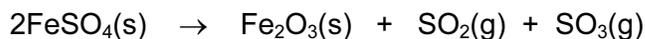
(iv) If the temperature is decreased to 300 °C, the yield of sulfur trioxide increases. Explain why this lower temperature is not used.

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

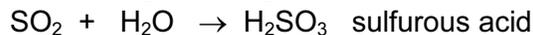
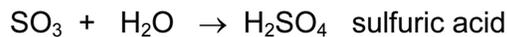
(v) Sulfur trioxide is dissolved in concentrated sulfuric acid. This is added to water to make more sulfuric acid. Why is sulfur trioxide not added directly to water?

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

- (b) Sulfuric acid was first made in the Middle East by heating the mineral, green vitriol, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$. The gases formed were cooled.



On cooling



- (i) How could you show that the first reaction is reversible?

.....
 [2]

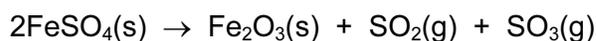
- (ii) Sulfurous acid is a reductant. What would you see when acidified potassium manganate(VII) is added to a solution containing this acid?

.....
 [2]

- (iii) Suggest an explanation why sulfurous acid in contact with air changes into sulfuric acid.

..... [1]

- (c) 9.12 g of anhydrous iron(II) sulfate was heated. Calculate the mass of iron(III) oxide formed and the volume of sulfur trioxide, at r.t.p., formed.



mass of one mole of $\text{FeSO}_4 = 152 \text{ g}$

number of moles of FeSO_4 used =

number of moles of Fe_2O_3 formed

mass of one mole of $\text{Fe}_2\text{O}_3 = \dots\dots\dots \text{ g}$

mass of iron(III) oxide formed =

number of moles of SO_3 formed =

volume of sulfur trioxide formed =

[6]

6 Sulphuric acid is made by the Contact process in the following sequence of reactions.



(a) (i) How is sulphur dioxide made from sulphur?

..... [1]

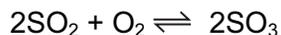
(ii) Sulphur dioxide has other uses.
Why is it used in the manufacture of paper?

..... [1]

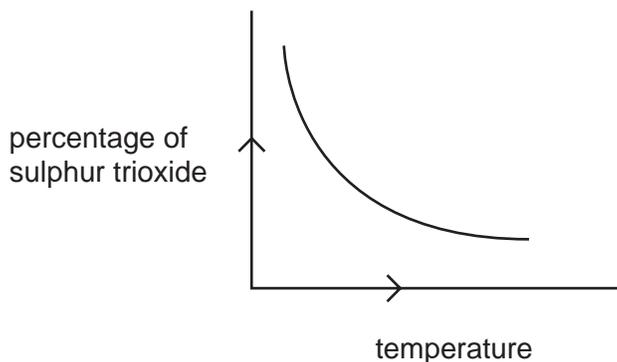
(iii) How does it preserve food?

..... [1]

(b) The equation for a stage of the Contact process is



The percentage of sulphur trioxide in the equilibrium mixture varies with temperature.



(i) How does the percentage of sulphur trioxide in the equilibrium mixture vary as the temperature increases? Circle the correct answer.

increases stays the same decreases [1]

(ii) Is the forward reaction in the equilibrium $2\text{SO}_2 + \text{O}_2 \rightleftharpoons 2\text{SO}_3$ exothermic or endothermic? Give a reason for your choice.

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

(iii) Explain, mentioning both rate and percentage yield, why the temperature used in the Contact process is 450°C .

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

(iv) Describe how the sulphur trioxide is changed into concentrated sulphuric acid.

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