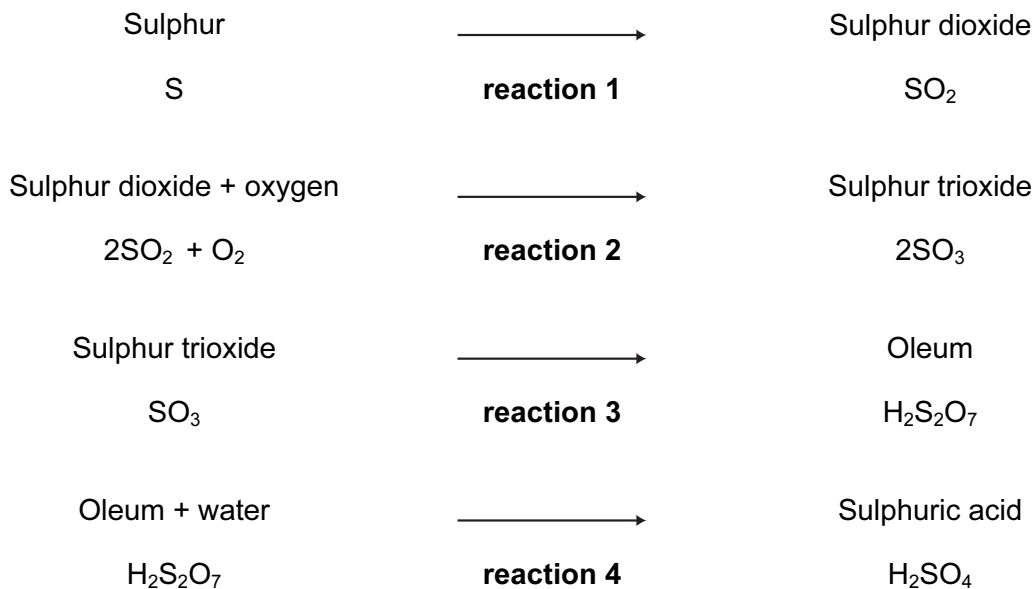1   Sulphur is used to make sulphuric acid. In the UK, the annual production of the acid is about 2.5 million tonnes.

(a) The reactions in the manufacture of sulphuric acid by the Contact Process are shown below.

| Sulphur | → | Sulphur dioxide |
| S | **reaction 1** | SO_2 |

| Sulphur dioxide + oxygen | → | Sulphur trioxide |
| $2SO_2 + O_2$ | **reaction 2** | $2SO_3$ |

| Sulphur trioxide | → | Oleum |
| SO_3 | **reaction 3** | $H_2S_2O_7$ |

| Oleum + water | → | Sulphuric acid |
| $H_2S_2O_7$ | **reaction 4** | H_2SO_4 |

(i)   Give a large scale source of the element sulphur.

.... [1]

(ii) State another use of sulphur dioxide.

.... [1]

(iii) How is sulphur changed into sulphur dioxide?

.... [1]

(iv) Name the catalyst used in reaction **2**.

.... [1]

(v)   Reaction **2** is exothermic. Why is a catalyst, rather than a higher temperature, used to increase the rate of this reversible reaction?

....

.... [2]

(vi) Write a word equation for reaction **3**.

.... [1]

(vii) Write a symbol equation for reaction **4**.

.... [1]

(b) About one third of this production of acid is used to make nitrogen and phosphorus-containing fertilisers.

(i) Name the third element that is essential for plant growth and is present in most fertilisers.

.... [1]

(ii) Name a nitrogen-containing fertiliser that is manufactured from sulphuric acid.

.... [1]

(iii) Rock phosphate (calcium phosphate) is obtained by mining. It reacts with concentrated sulphuric acid to form the fertiliser, superphosphate. Predict the formula of each of these phosphates.

fertiliser	ions	formula
calcium phosphate	Ca^{2+} and PO_4^{3}	....
calcium superphosphate	Ca^{2+} and H_2PO_4	.... [2]

(iv) The ionic equation for the reaction between the phosphate ion and sulphuric acid is shown below.

$$PO_4^{3} \quad + \quad {}_2SO_4 \quad \rightarrow \quad H_2PO_4 \quad + \qquad {}_4$$
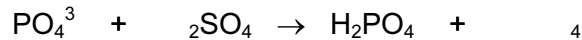
Explain why the phosphate ion is described as acting as a base in this reaction.

.... [2]

2 Sulphur dioxide, ₂ ₃ ur.

(a) Sulphur dioxide can kill bacteria and has bleaching properties. Give a use of sulphur dioxide that depends on each of these properties.

  (i) ability to kill bacteria ....[1]

  (ii) bleaching properties ....[1]

(b) Sulphur trioxide can be made from sulphur dioxide.

  (i) Why is this reaction important industrially?

    ....[1]

  (ii) Complete the word equation.

    sulphur dioxide + ……………………………………… $\rightarrow$ sulphur trioxide   [1]

  (iii) What are the conditions for this reaction?

    ....

    ....[2]

(c) Sulphur dioxide is easily oxidised in the presence of water.

$$SO_2 + 2H_2O - 2e^- \rightarrow SO_4^{2-} + 4H^+$$
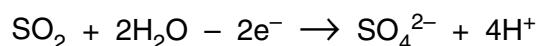
  (i) What colour change would be observed when an excess of aqueous sulphur dioxide is added to an acidic solution of potassium manganate(VII)?

    ....[2]
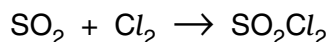
  (ii) To aqueous sulphur dioxide, acidified barium chloride solution is added. The mixture remains clear. When bromine is added, a thick white precipitate forms. What is the white precipitate? Explain why it forms.

    ....

    ....[3]

(d) Sulphur dioxide reacts with chlorine in an addition reaction to form sulphuryl chloride.

$$SO_2 + Cl_2 \rightarrow SO_2Cl_2$$

8.0 g of sulphur dioxide was mixed with 14.2 g of chlorine. The mass of one mole of SO_2Cl_2 is 135 g.

Calculate the mass of sulphuryl chloride formed by this mixture.

Calculate the number of moles of SO_2 in the mixture = ………………

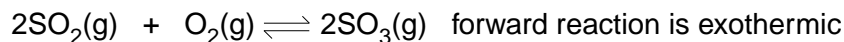Calculate the number of moles of Cl_2 in the mixture = ………………

Which reagent was not in excess? ………………………….

How many moles of SO_2Cl_2 were formed = ………………

Physics Calculate the mass of sulphuryl chloride formed = ………… g   [5]

3 **(a)** Sulphuric acid is made by the Contact Process.

$$2SO_2(g) \; + \; O_2(g) \rightleftharpoons 2SO_3(g) \quad \text{forward reaction is exothermic}$$

(i) What are the reaction conditions for the Contact Process?

....

....[3]

(ii) Would the yield of sulphur trioxide increase, decrease or stay the same when the temperature is increased? Explain your answer.

....

....

....[2]

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

....

....[2]

(b) There are three ways of making salts from sulphuric acid.
titration using a burette and indicator
precipitation by mixing the solutions and filtering
neutralisation of sulphuric acid using an excess of an insoluble base

Complete the following table of salt preparations.

method	reactant 1	reactant 2	salt
titration	sulphuric acid		sodium sulphate
neutralisation	sulphuric acid		zi sulphate
precipitation	sulphuric acid		barium sulphate
	sulphuric acid	copper(II) oxide	copper(II) sulphate

[4]

(c) The results of an investigation into the action of heat on copper(II) sulphate-5-water, a blue crystalline solid, are given below.

The formula is $CuSO_4.5H_2O$ and the mass of one mole is 250 g

A 5.0 g sample of the blue crystals is heated to form 3.2 g of a white powder. With further heating this decomposes into a black powder and sulphur trioxide.

(i) Name the white powder.

....[1]

(ii) What is observed when water is added to the white powder?

....[1]

(iii) Name the black powder.

....[1]

(iv) Calculate the mass of the black powder. Show your working.

....

....

....[3]

4 Iron pyrite, FeS_2, is known as Fool's Gold because it is a shiny yellow solid which is similar in appearance to gold. Iron pyrite is an ionic compound. Gold is a metallic element.

(a) Iron pyrite, FeS_2, contains positive and negative ions. The positive ion is Fe^{2+}.

Deduce the formula of the negative ion.

.... [1]

(b) A student is provided with a sample of iron pyrite and a sample of gold.

Suggest how the student could distinguish between the two substances.

....

.... [2]

(c) Sulfur dioxide is produced on a large scale by heating iron pyrite strongly in air. The iron pyrite reacts with oxygen in the air producing iron(III) oxide, Fe_2O_3, and sulfur dioxide.

(i) Construct a chemical equation for the reaction between iron pyrite and oxygen.

.... [2]

(ii) Give **one** use of sulfur dioxide.

.... [1]

[Total: 6]

5 **(a)** Coal is a solid fossil fuel.

Name **two** other fossil fuels.

.... [2]

(b) Two of the elements present in a sample of coal are carbon and sulfur.

A sample of coal was heated in the absence of air and the products included water, ammonia and hydrocarbons.

Name **three** other elements present in this sample of coal.

.... [2]

(c) Sulfur, present in coal, is one major cause of acid rain. Sulfur burns to form sulfur dioxide which reacts with rain water to form sulfuric acid.

(i) Describe how the high temperatures in vehicle engines are another cause of acid rain.

....

....

.... [3]

(ii) Give **two** harmful effects of acid rain.

....

.... [2]

(d) In 2010, a large coal-burning power station in the UK was converted to burn both coal and wood.

Explain why the combustion of wood rather than coal can reduce the effect of the emissions from this power station on the level of carbon dioxide in the atmosphere.

....

....

....

.... [3]

[Total: 12]