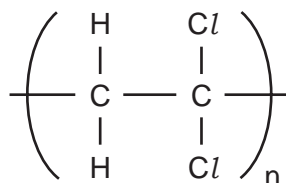1   Polymers are extensively used in food packaging. Poly(dichloroethene) is used because gases can only diffuse through it very slowly. Polyesters have a high thermal stability and food can be cooked in a polyester bag.

   (a) (i) The structure of poly(dichloroethene) is given below.

      Draw the structural formula of the monomer.

      [1]

      (ii) Explain why oxygen can diffuse faster through the polymer bag than carbon dioxide can.

      ....
      [2]

   (b) (A polyester can be formed from the monomers $HO\text{-}CH_2CH_2\text{-}OH$ and $HOOC\text{-}C_6H_4\text{-}COOH$. Draw the structure of this polyester.

      [2]

(Ii) Name a naturally occurring class of compounds that contains the ester linkage.

[1]

(iii) Suggest what is meant by the term *thermal stability.*

[1]

(c) (Describe **two** environmental problems caused by the disposal of plastic (polymer) waste.

[2]

(ii) The best way of disposing of plastic waste is recycling to form new plastics. What is another advantage of recycling plastics made from petroleum?
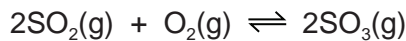
[1]

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.

$$2SO_2(g) \ + \ O_2(g) \ \rightleftharpoons \ 2SO_3(g)$$

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 $1\,dm^3$ of oxygen?

.... dm^3 [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]

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(e) A low pressure, 2 atmospheres, is used. At equilibrium, about 98% SO_3 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 halogens are a group of non-metals in Group VII of the Periodic Table.

(a) The reactivity of the halogens decreases down the group.

Describe an experiment which shows that chlorine is more reactive than iodine. Include an equation in your answer.

....

....

....

.... [3]

**(b)** The halogens form interhalogen compounds. These are compounds which contain two different halogens.

Deduce the formula of the compound which has the composition 0.013 moles of iodine atoms and 0.065 moles of fluorine atoms.

....

.... [2]

(c) Iodine reacts with chlorine to form a dark brown liquid, iodine monochloride.

chlorine
supplied

crystals
of iodine

$$I_2(s) \ + \ Cl_2(g) \ \rightarrow \ 2ICl(l)$$
dark brown
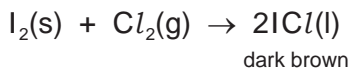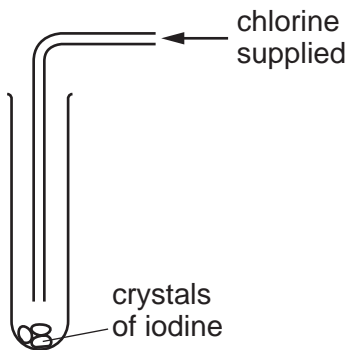
When more chlorine is added and the tube is sealed, a reversible reaction occurs and the reaction comes to equilibrium.

$$ICl(l) \ + \ Cl_2(g) \ \rightleftharpoons \ ICl_3(s)$$
dark brown $\qquad\qquad$ yellow
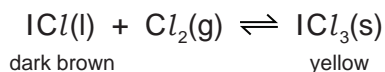
(i) Give another example of a reversible reaction.

.... [1]

(ii) Explain the term *equilibrium*.

....

.. [2]

(d) Chlorine is removed from the tube and a new equilibrium is formed.

Explain why there is less of the yellow solid and more dark brown liquid in the new equilibrium mixture.

....

....

.... [2]

(e) A sealed tube containing the equilibrium mixture is placed in ice-cold water. There is an increase in the amount of yellow solid in the equilibrium mixture.

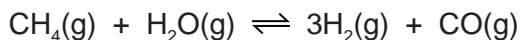What can you deduce about the forward reaction in this equilibrium?

$$IC l(l) \ + \ C l_2(g) \ \rightleftharpoons \ IC l_3(s)$$
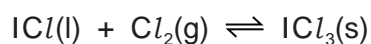
Explain your deduction.

....

....

....

.... [3]
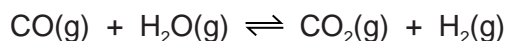
[Total: 13]

4 At present the most important method of manufacturing hydrogen is steam reforming of methane.

(a) In the first stage of the process, methane reacts with steam at 800 °C.

$$CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g)$$

In the second stage of the process, carbon monoxide reacts with steam at 200 °C.

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

(i) Explain why the position of equilibrium in the first reaction is affected by pressure but the position of equilibrium in the second reaction is not.

....

....

.... [2]

(ii) Suggest why a high temperature is needed in the first reaction to get a high yield of products but in the second reaction a high yield is obtained at a low temperature.

....

.... [2]

(b) Two other ways of producing hydrogen are cracking and electrolysis.

(i) Hydrogen can be a product of the cracking of long chain alkanes.
Complete the equation for the cracking of C_8H_{18}.

$$C_8H_{18} \rightarrow 2............ + H_2$$ [1]

(ii) There are three products of the electrolysis of concentrated aqueous sodium chloride. Hydrogen is one of them.
Write an equation for the electrode reaction which forms hydrogen.

.... [2]

(iii) Name the other **two** products of the electrolysis of concentrated aqueous sodium chloride and give a use of each one.

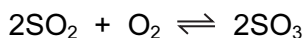product ....   use ....

product ....   use ....   [4]

[Total: 11]

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

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

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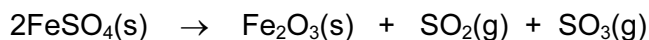
(iv) If the temperature is decreased to 300 °C, the yield of sulfur trioxide increases. Explain why this lower temperature is not used.

....

.... [1]
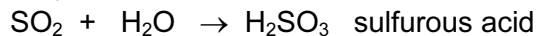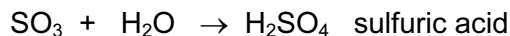
(v) Sulfur trioxide is dissolved in concentrated sulfuric acid. This is added to water to make more sulfuric acid. Why is sulfur trioxide not added directly to water?

....

.... [1]

$$2SO_2 + O_2 \rightleftharpoons$$

(b) Sulfuric acid was first made in the Middle East by heating the mineral, green vitriol, $FeSO_4.7H_2O$. The gases formed were cooled.

$FeSO_4.7H_2O(s)$ $\rightarrow$ $FeSO_4(s)$ + $7H_2O(g)$
green crystals   yellow powder

$2FeSO_4(s)$ $\rightarrow$ $Fe_2O_3(s)$ + $SO_2(g)$ + $SO_3(g)$

On cooling

SO_3 + H_2O $\rightarrow$ H_2SO_4 sulfuric acid
SO_2 + H_2O $\rightarrow$ H_2SO_3 sulfurous acid

(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.

$2FeSO_4(s)$ $\rightarrow$ $Fe_2O_3(s)$ + $SO_2(g)$ + $SO_3(g)$
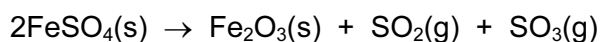
mass of one mole of $FeSO_4$ = 152 g

number of moles of $FeSO_4$ used   = ...

number of moles of Fe_2O_3 formed   = ...

mass of one mole of Fe_2O_3 = ... g

mass of iron(III) oxide formed   = ... g

number of moles of SO_3 formed   = ...

volume of sulfur trioxide formed   = ... dm^3

[6]

[Total: 16]