OCR
RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE

CHEMISTRY B (SALTERS)

Candidates answer on the Question Paper

OCR Supplied Materials:
- *Data Sheet for Chemistry B (Salters)* (inserted)
- *Advance Notice: 'Treating the Public Water Supply'* (inserted)

Other Materials Required:
- Scientific Calculator

Duration: 1 hour 45 minutes

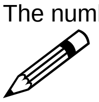
Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
-  Where you see this icon you will be awarded marks for the quality of written communication in your answer.
  This means for example you should:
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- You may use a scientific calculator.
- The insert *'Treating the Public Water Supply'* is provided for use with question 5.
- A copy of the *Data Sheet for Chemistry B (Salters)* is provided as an insert with this question paper.
- You are advised to show all the steps in any calculations.
- The total number of marks for this paper is **100**.

Answer **all** the questions.

1 Natural processes in the air can control the concentrations of some types of atmospheric pollutants. Although carbon monoxide emissions increased in the twentieth century, the percentage of carbon monoxide in the troposphere has remained almost constant.

(a) The increased use of cars in the twentieth century is one reason for the increase in carbon monoxide emissions.

Explain the origin of these carbon monoxide emissions.

....

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.... **[2]**

(b) Give **two** reasons why carbon monoxide is classed as a polluting gas.

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.... **[2]**

(c) The reaction of carbon monoxide with hydroxyl radicals helps control atmospheric carbon monoxide concentrations. Hydroxyl radicals form by the breakdown of water molecules.

(i) Name the type of bond breaking process that occurs to form hydroxyl radicals from water molecules.

.... **[1]**

(ii) The bond enthalpy for the O–H bond is $+464\,kJ\,mol^{-1}$. Calculate the energy, in Joules, needed to break a **single** O–H bond.

Avogadro constant, $N_A = 6.02 \times 10^{23}\,mol^{-1}$

energy = ... J **[2]**

(iii) Calculate the frequency of radiation that is needed to break a single O-H bond.

Give your answer to **three** significant figures.

Planck constant, $h = 6.63 \times 10^{-34}\,J\,Hz^{-1}$

frequency = ... Hz **[3]**

(d) **Equation 1.1** represents the reaction of hydroxyl radicals with carbon monoxide to produce carbon dioxide.

$$CO + OH \rightarrow CO_2 + H$$ **equation 1.1**

(i) Explain what is meant by the term *radical*.

....

.... **[1]**

(ii) Draw a '*dot-and-cross*' diagram to show that OH is a radical.

[2]

(iii) Classify the reaction represented by **equation 1.1** as initiation, propagation or termination. Explain your choice.

....

....

.... **[2]**

(e) The reaction represented by **equation 1.1** produces carbon dioxide, which is a gas at room temperature. Silicon dioxide, another Group 4 oxide, is a solid at room temperature.

Explain this difference in terms of bonding and structure.

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....

.... **[3]**

(f) Scientists monitor the composition of the Earth's atmosphere. They have found that the concentration of carbon dioxide in dry, unpolluted tropospheric air has increased from 300 ppm to around 380 ppm between 1900 and the present day.

(i) Taking the present day value to be 380 ppm, calculate the **increase** in the percentage of carbon dioxide in the air between 1900 and the present day.

increase in carbon dioxide concentration = ... % **[1]**

(ii) Carbon dioxide is described as a 'greenhouse gas'. Greenhouse gases absorb infrared radiation in the troposphere.

Explain the source of the infrared radiation absorbed by carbon dioxide and the possible link between increased concentrations of carbon dioxide in the troposphere and global warming.

In your answer, you should make it clear how the steps you describe are linked to one another.

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.... **[6]**

(g) Carbon monoxide is used as a reactant for the production of propanal, CH_3CH_2CHO, from ethene.

(i) Name the homologous series to which propanal belongs.

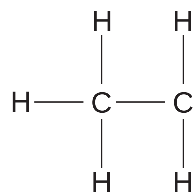
.... **[1]**

(ii) Suggest the equation for the reaction in which propanal is made from carbon monoxide, ethene and another reagent.

$$\rightarrow$$

[2]

(iii) Complete the diagram below to show the full structural formula for propanal.



[1]

[Total: 29]

2 Chloromethane, CH_3Cl, and bromomethane, CH_3Br, are naturally occurring. Bromomethane is produced by seaweed in ocean water. It is also manufactured for a variety of agricultural and industrial uses.

(a) Name the homologous series to which bromomethane belongs.

.... **[1]**

(b) Bromomethane can be manufactured from methanol and hydrogen bromide.

(i) Write the equation for the reaction between methanol and hydrogen bromide.

$\rightarrow$

[2]

(ii) Circle **two** words from the following list that best describe what is happening in the reaction of methanol with hydrogen bromide.

addition **electrophilic** **elimination** **nucleophilic** **radical** **substitution** **[2]**

(c) Bromomethane reacts with a solution of ammonia when heated in a sealed tube. One product of this reaction is **compound A**, which is an organic compound.

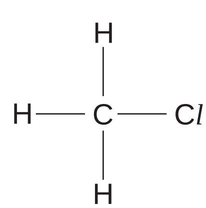
(i) Name the homologous series to which **compound A** belongs.

.... **[1]**

(ii) Write the formula of **compound A**.

.... **[1]**

(d) The C–Cl bond in chloromethane is slightly polar. On the diagram of the CH_3Cl molecule shown below, mark the partial charges on the atoms.



[1]

(e) Draw a diagram to represent the three-dimensional **shape** of a molecule of CH_3Cl and give the bond angle.

Bond angle: .... ° **[2]**

(f) Bromomethane and chloromethane are both present in the atmosphere. Explain how chloromethane causes ozone depletion in the stratosphere **and** suggest why bromomethane has a lower ozone depleting potential than chloromethane.

In your answer, you should use appropriate technical terms, spelled correctly.

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.... **[5]**

(g) Scientists working in the 1980s discovered the problem of ozone depletion in the stratosphere when they were studying the Earth's atmosphere over the Antarctic.

The scientists used a new instrument to take a second set of readings for their experiment because they did not think their first results were correct.

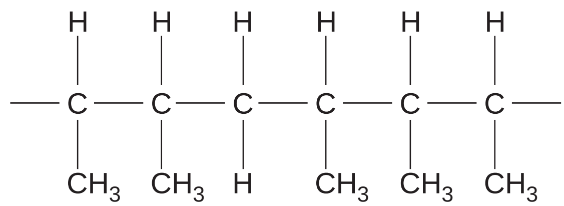
Why did the scientists think their results from the first experiment were incorrect?

....

.... **[1]**

[Total: 16]

3 Co-polymers have a variety of uses. The diagram below shows a section of **co-polymer A**, which is produced from but-2-ene and another alkene monomer.



co-polymer A

(a) (i) Name the **type** of polymerisation that produces **co-polymer A**.

.... **[1]**

(ii) Give the name and full structural formula of the other alkene monomer that is reacted with but-2-ene to produce **co-polymer A**.

Name: ....

Full structural formula:

[2]

(b) The monomers used to make **co-polymer A** are both alkenes. Describe a simple chemical test for an alkene.

(i) aqueous reagent used.

.... **[1]**

(ii) colour change seen during the test.

from .... to .... **[2]**

(c) But-2-ene has *E*/*Z* isomers. Draw diagrams of the two isomers and label them as either ***E*** or ***Z***.

[2]

(d) Name the type of intermolecular bond that could form between two chains of **co-polymer A**.

.... **[1]**

(e) The uses of polymers and co-polymers are linked to their properties.

(i) Poly(but-2-ene) has been used to make pipes for water supplies. Suggest a property of poly(but-2-ene) that makes it suitable for this use.

....

.... **[1]**

(ii) **Co-polymer A** has a low density and is cheap to manufacture. It can be produced as a film that has a high tensile strength. Suggest a use that could be made of this co-polymer film.

....

.... **[1]**

[Total: 11]

4 A student decided to make some propene from propan-1-ol.

(a) Propan-1-ol is a liquid at room temperature, whilst propene is a gas. The strongest type of intermolecular bond between propan-1-ol molecules is hydrogen bonding.

(i) Draw a diagram to show the hydrogen bonding between **two** propan-1-ol molecules. Include relevant lone pairs and partial charges in your diagram.

[4]

(ii) Propan-1-ol has a higher boiling point than propene. Explain this in terms of intermolecular bonding.

In your answer, you should make it clear how the steps you describe are linked to one another.

[4]

(b) **Equation 4.1** represents the reaction that occurs when propene forms from propan-1-ol.

$$CH_3CH_2CH_2OH(g) \rightleftharpoons CH_3CH{=}CH_2(g) + H_2O(g) \qquad \Delta H = +81\ kJ\ mol^{-1}$$ **equation 4.1**

Underline the term below that describes the type of reaction occurring in **equation 4.1**.

addition **elimination** **hydrolysis** **substitution** **[1]**

(c) Give the reagents and conditions required for the reaction represented by **equation 4.1**.

[3]

(d) The reaction represented by **equation 4.1** can reach a position of dynamic equilibrium. Explain what is meant by the term *dynamic equilibrium*.

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.... **[2]**

(e) Describe and explain the effect of the following changes on the equilibrium amount of propene produced in the reaction represented by **equation 4.1**.

(i) Increasing the total pressure of the reaction system.

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.... **[2]**

(ii) Carrying out the reaction at a higher temperature.

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.... **[2]**

(f) Describe and explain what happens to the **rate** of the reaction represented by **equation 4.1** if the pressure is increased.

....

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.... **[3]**

(g) The student used the propene for a range of chemical reactions. Give the structural formula of a product that forms if the student reacts the propene with:

(i) hydrogen bromide

[1]

(ii) hydrogen

[1]

(h) The student carried out the reaction of propene with hydrogen at room temperature and pressure by carefully choosing the catalyst to use. Name the catalyst that would be required under these reaction conditions.

.... **[1]**

[Total: 24]

5 This question is based on the Advance Notice article '**Treating the Public Water Supply: What is in Your Water, and How is it Made Safe to Drink?**' which is provided as an insert to this paper.

(a) Suggest what is meant by the term *oxidant* as used in the article. Give an example of an oxidant from the article. Explain your choice in terms of oxidation states.

Definition: ....

....

....

Example and explanation: ....

....

....

.... **[4]**

(b) Write the ionic equation for the formation of aluminium hydroxide during the coagulation process using HCO_3^- ions. Include state symbols.

$$\rightarrow$$

[3]

(c) Lime, soda ash and HCO_3^- are involved in water softening. Give the systematic names for lime, soda ash and HCO_3^-.

lime ....

soda ash ....

HCO_3^-.. **[3]**

(d) The article states that the ion exchange process removes calcium ions from water and replaces them with sodium ions. Suggest why calcium ions displace sodium ions from the ion exchange resin.

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.... **[2]**

(e) 800 cm^3 of hard water, containing calcium ions at a concentration of 0.0020 $mol\,dm^{-3}$, are passed through an ion exchanger.

Calculate the mass, in g, of sodium ions that are collected from the process. Assume that the exchange process is 100% efficient.

mass of sodium ions = ... g **[3]**

(f) Explain the benefits and disadvantages of using chlorine to treat drinking water. Include references to the transport and storage of chlorine.

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Treating the Public Water Supply: What is in Your Water, and How is it Made Safe to Drink?

Adapted from "Treating the Public Water Supply: What is in Your Water and How is it Made Safe to Drink" on Washington University, St Louis, Chemistry Department website.

Species (other than H_2O) Contained in Water

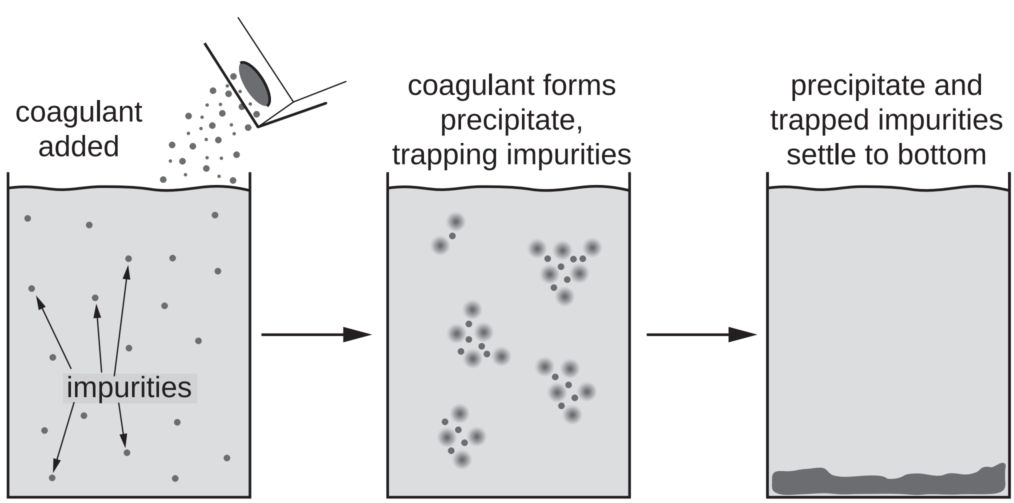
Chemical analysis of virtually any freshwater sample reveals that "water", even water that has been rigorously cleaned and treated, is really a solution containing many dissolved species. A solution is a homogeneous system (a system that is uniform throughout) containing more than one substance. A solution in which water is the solvent is known as an aqueous solution. In addition to water (the solvent), freshwater samples may include:

- ions (*e.g.*: Na^+, Ca^{2+}, F^- and HSO_4^-)
- dissolved gases (*e.g.*: O_2 and CO_2)
- other natural dissolved molecules (*e.g.*: organic by-products of decaying leaves)
- dissolved molecules from human activity (*e.g.*: industrial and agricultural wastes)

Two processes, known as flocculation and coagulation, are used to create larger particles that will settle quickly to the bottom. In flocculation, small particles with non-rigid surfaces are made to agglomerate by stirring the water (and thus bringing the particles into contact with one another so that the surfaces can become stuck together).

When the agglomeration of the particles gets large enough, the aggregate can settle in still water by sedimentation. Other suspended particles do not agglomerate well by flocculation. To remove these particles from the water, coagulation must be used. Coagulation is the process of gathering particles into a cluster or clot, often achieved by the addition of special chemicals known as coagulants. The most common coagulant used in water-treatment facilities is aluminium sulfate, $Al_2(SO_4)_3$. Other Al and Fe salts, including poly-aluminium chloride, ferric chloride, and ferric sulfate, may be used as well. These salts react with ions naturally found in the water to produce a solid precipitate of aluminium hydroxide. As this precipitate forms, other particles are caught in the solid, forming a mass that will settle to the bottom via sedimentation.

$$Al^{3+} + SO_4^{2-} + Ca^{2+} + 3HCO_3^- \rightarrow Al(OH)_3 + CaSO_4 + 3CO_2$$



Treating Water Hardness

The process of removing Ca^{2+} and Mg^{2+} from the water is known as **water softening**. Two minerals, **lime**, $Ca(OH)_2$ and **soda ash**, Na_2CO_3, are typically used to soften public water supplies. When lime is added to water, it dissolves to give three aqueous (solvated) ions: one Ca^{2+} ion and two OH^- ions for each unit of $Ca(OH)_2$. Likewise, soda ash dissolves to give two Na^+ ions and one CO_3^{2-} ion for each unit of Na_2CO_3 that dissolves.

A number of reactions occur to generate the insoluble precipitates $CaCO_3(s)$ and $Mg(OH)_2(s)$ from the Ca^{2+} and Mg^{2+} ions. The most important reaction for the removal of Mg^{2+} is shown below.

$$Mg^{2+}(aq) + 2OH^-(aq) \rightarrow Mg(OH)_2(s)$$

The important reaction for the removal of Ca^{2+} ions is:

$$\underset{\text{from water}}{Ca^{2+}(aq)} + \underset{\text{from lime}}{Ca^{2+}(aq)} + \underset{\text{from soda ash}}{2CO_3^{2-}(aq)} \rightarrow \underset{\text{precipitate}}{2CaCO_3(s)}$$

The solids generated by the water-softening precipitation reaction are then removed by sedimentation or filtration. If an excess of lime was used to precipitate magnesium ions in the water, some unused hydroxide (OH^-) ions will remain in the water after the calcium is precipitated, resulting in a high (or alkaline) pH. If necessary, the pH can be lowered by bubbling carbon dioxide gas through the water. The equations for this are given below:

$$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$$

$$H_2CO_3(aq) + OH^-(aq) \rightleftharpoons H_2O + HCO_3^-(aq)$$

HCO_3^- remaining in the water is non-toxic and does not adversely affect the flavour of the water.

Removing Iron and Manganese

Two types of precipitation reactions may be used to remove Fe^{2+} and Mn^{2+} from the water. The most important of these reactions is **oxidation**. Using molecular oxygen (O_2) or another oxidant such as potassium permanganate, $KMnO_4$, Fe(II) is readily oxidised to Fe(III) in solution.

$$3Fe^{2+}(aq) + MnO_4^-(aq) + 2H_2O(l) \rightarrow 3Fe^{3+}(aq) + MnO_2(s) + 4OH^-(aq)$$

If the solution is alkaline (high pH), the Fe(III) forms $Fe(OH)_3$ and precipitates. Hence, adding an oxidant to the water and raising the water's pH at the water-treatment plant forms an insoluble precipitate. The insoluble hydroxide can then be removed by sedimentation or filtration. The water-softening agents described in the "Treating Water Hardness" section above can also help to make insoluble precipitates from Fe^{2+} and Mn^{2+}.

Disinfection

In many water supplies, the most serious health threats are posed not by chemicals, but by infectious organisms (bacteria) in the water. Chlorine (Cl_2) is a major disinfectant that is cheap and kills most of the serious disease-causing bacteria in the water. However, chlorine is difficult to store and transport. This is because chlorine is a toxic gas at room temperature and pressure. This would mean that chlorine could diffuse across a large region, if an accident occurs during its transportation, endangering any people near the accident site. Even in small amounts, chlorine gas can cause respiratory problems. Chlorine disinfection also results in a wide variety of by-products. One class of chlorination by-products, known as trihalomethanes (THM's) are suspected carcinogens. Because of concern about these by-products in the water supply, chlorine is now kept to minimum levels, and other methods of disinfection are being used more frequently. Chloramines form more stable disinfectants and pose less risk of harmful by-products, but cost more to use. Other methods focus on removing the organisms through coagulation, sedimentation, and improved filtration.

Adsorption

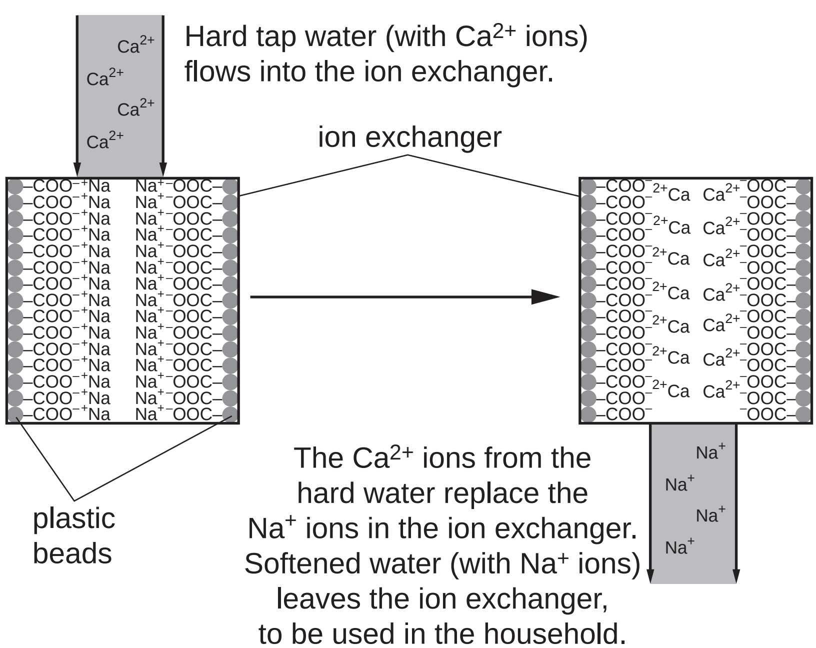
Dissolved organic compounds in water (*e.g.* herbicides such as atrazine, and industrial waste products) can pose a significant health threat, and may affect the taste and odour of drinking water. To remove them, the process of **adsorption** is used. Adsorption is a process in which one substance is attached to the surface of another substance. **Powdered activated carbon** (PAC), a finely ground charcoal, is used for this process. When PAC is added to the water, the organic compounds attach to the surface of the powder granules. The granules of PAC have irregularly shaped surfaces, which gives PAC a very large surface area to attract organic compounds. It is estimated that 1 gram of PAC has a surface area of around 1000 m^2! The carbon can then be removed by filtration, taking the unwanted organic compounds with it.

Addition of Other Chemicals to the Water Supply

Certainly a principal objective of the water-treatment process is to remove substances from water that are harmful, or that otherwise make the water unsuitable for human use. However, another important component of the process is the addition of chemicals that make the water better for human use. For example, fluoride (F^-) is routinely added to public water supplies to protect the teeth of those who drink the water. Cities that add appropriate amounts of fluoride to their drinking-water supplies have successfully reduced the incidence of cavities among the children who inhabit those cities. The processes of screening, sedimentation, precipitation, filtration, adsorption, and disinfection work together to remove the unwanted substances from our water supply making it safe to drink and appropriate for other uses. Additions of other chemicals, such as fluoride, further enhance the quality of the water for drinking.

Point-of-Use Water Softeners

Household water softeners, shown as a schematic diagram below, typically use a different process from the precipitation reaction described above, known as ion exchange. Ion-exchange devices consist of a bed of plastic (polymer) beads covalently bound to anion groups, such as $-COO^-$. The negative charge of these anions is balanced by Na^+ cations attached to them. When water containing Ca^{2+} and Mg^{2+} is passed through the ion exchanger, the Ca^{2+} and Mg^{2+} ions are more attracted to the anion groups than the Na^+ ions. Hence, they replace the Na^+ ions on the beads, and so the Na^+ ions (which do not form scummy residues) go into the water in place of the Ca^{2+} and Mg^{2+}.



When hard tap water passes through the ion exchanger, the calcium ions from the tap water replace the sodium ions in the ion exchanger. Each calcium ion displaces two sodium ions during this process. the softened water, containing sodium ions in place of calcium ions, can be collected for household use.

Unfortunately, many people with high blood pressure or other health problems must restrict their intake of sodium ions. Because water softened by this type of ion exchange contains many sodium ions, people with limited sodium intakes should avoid drinking water that has been softened this way. Several new techniques for softening water without introducing sodium ions are beginning to appear on the market.

Point-of-Use Adsorption Filters

Many of the contaminants that make our drinking water unsafe or unpleasant to drink, such as lead ions (which may be leached into the water from lead pipes) or organic molecules producing offensive odours and tastes, can be removed by adsorption-filtration devices installed at the tap. These devices have filters containing powdered activated carbon, which adsorbs the offending contaminants in the water. As the water for consumption exits the device, the PAC (with the unwanted contaminants attached) is strained out of the water by the filter. Periodically, the filter must be replaced so that it does not become clogged and ineffective.

Completing the Cycle: What Happens to Water After We Use It?

Once water has been used, it must somehow re-enter the freshwater supply. Some of the water is evaporated (*e.g.*: if it is used to generate steam for industry, or if we drink the water and then sweat). The evaporated water eventually collects in clouds and returns to the earth via precipitation. However, most of the water that we use remains in the liquid state, and is returned to the freshwater supply directly (as run-off) or via wastewater treatment facilities.

END OF ADVANCE NOTICE ARTICLE