

## Environmental Chemistry (Water) | Solved Exercise

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### Multiple Choice Questions

i. Total volume of water on earth surface is:

**Answer: b) 1.33 billion km<sup>3</sup>**

ii. Vital function of protoplasm is due to presence of:

**Answer: a) Water**

iii. Quantity of fresh water on earth surface is only about:

**Answer: a) 2.6%**

iv. In water, ratio of oxygen and hydrogen by mass is:

**Answer: c) 8:1** (Oxygen = 16, Hydrogen = 2, so O:H = 16:2 = 8:1)

v. Unusual physical properties of water are due to:

**Answer: a) Hydrogen bonding**

vi. Density of water is 1 g/cm<sup>3</sup> at:

**Answer: b) 4°C**

vii. Volume of water increases when temperature decreases below:

**Answer: a) 4°C**

viii. Enormous quantity of water acts as giant thermostat due to its high:

**Answer: c) Heat capacity**

ix. Latent heat of fusion of water is:

**Answer: b) 6 kJ/mol**

x. Dielectric constant of water at 18°C is:

**Answer: d) 80**

xi. Water gas is a mixture of:

**Answer: c) Carbon monoxide & hydrogen**

xii. Chlorine acts as bleaching agent in presence of:

**Answer: b) H<sub>2</sub>O**

xiii. Chemical formula of magnetic oxide is:

**Answer: a) Fe<sub>3</sub>O<sub>4</sub>**

xiv. Rain water is acidic in nature because air contains:

**Answer: b) Carbon dioxide**

xv. Nutrient pollution of water bodies is caused by:

**Answer: c) Nitrates & Phosphates**

xvi. Most aquatic animals cannot survive above:

**Answer: d) 40°C**

xvii. Disease caused by mercury is:

**Answer: a) Parkinson**

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### Short Answers

**i. Why do temperatures of coastal areas remain moderate throughout the year?**

Water has a very high specific heat capacity (4.18 J/g°C). The large oceans and seas near coastal areas absorb a huge amount of heat in summer without getting very hot, and slowly release this heat in winter without getting very cold. This keeps the temperature of coastal areas moderate throughout the year.

**ii. Why does ice float on the surface of water?**

When water cools below 4°C and freezes, its molecules arrange themselves into a cage-like open crystalline structure due to hydrogen bonding. In this structure, water molecules are farther apart than in liquid water. This makes ice less dense (0.92 g/cm<sup>3</sup>) than liquid water (1 g/cm<sup>3</sup>). Since ice is less dense, it floats on the surface of water.

**iii. Why is H<sub>2</sub>O liquid at room temperature while H<sub>2</sub>S is a gas?**

Water (H<sub>2</sub>O) molecules form strong hydrogen bonds with each other because oxygen is highly electronegative. These hydrogen bonds require a large amount of energy to break. Therefore, water has a high boiling point (100°C) and is liquid at room temperature.

H<sub>2</sub>S cannot form hydrogen bonds because sulfur is less electronegative and has a larger atomic size. So H<sub>2</sub>S has a very low boiling point (-60°C) and remains a gas at room temperature.

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**iv. How does the enormous quantity of water act as a giant thermostat?**

Due to its very high heat capacity, water absorbs or releases large amounts of heat with very little change in its own temperature. The vast oceans, seas and lakes absorb heat from the sun during summer and slowly release it during winter. This keeps the Earth's temperature relatively stable and prevents extreme temperature changes — just like a thermostat controls the temperature of a room.

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**v. Why does water have a soothing effect on the body in summer?**

Water has a very high latent heat of evaporation (44 kJ/mol). When sweat (water) evaporates from the surface of our skin, it absorbs a large amount of heat from the body. This heat loss cools the body down and gives a soothing and refreshing effect in hot summer weather.

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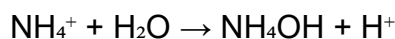
**vi. Why is water called a universal solvent?**

Water is called a universal solvent because it can dissolve more substances than any other liquid. Reasons are:

- Water is a polar molecule with partial positive ( $\delta^+$ ) and negative ( $\delta^-$ ) charges, which attract the ions of ionic compounds and dissolve them
  - Its very high dielectric constant (80) weakens the force of attraction between ions, helping them separate and dissolve
  - Water molecules form hydrogen bonds with many polar substances, helping them dissolve
  - It can dissolve ionic compounds (NaCl), gases (CO<sub>2</sub>, O<sub>2</sub>), acids, bases and many organic molecules
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**vii. The aqueous solution of ammonium chloride is acidic. Why?**

$\text{NH}_4\text{Cl}$  is a salt formed from a weak base ( $\text{NH}_4\text{OH}$ ) and a strong acid ( $\text{HCl}$ ). When it dissolves in water,  $\text{NH}_4^+$  ions react with water (hydrolysis):

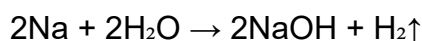


The  $\text{H}^+$  ions produced make the solution acidic. Since the base formed ( $\text{NH}_4\text{OH}$ ) is weak and the acid ( $\text{HCl}$ ) is strong, the solution is acidic.

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**viii. Why does fire start burning on water when sodium is put into it?**

Sodium reacts vigorously with water producing sodium hydroxide and hydrogen gas:



This reaction is highly exothermic (releases a large amount of heat). The heat produced is enough to ignite the hydrogen gas that forms. The hydrogen gas burns on the surface of water, which is why we see fire on water.

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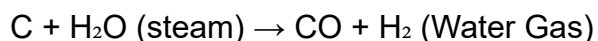
**ix. Why is it advisable to drink boiled water?**

Water from natural sources contains harmful microorganisms such as bacteria, viruses and parasites that cause diseases like cholera, typhoid and dysentery. When water is boiled, the high temperature kills all these disease-causing organisms. Boiling also removes dissolved gases and some volatile impurities. Therefore, boiled water is safe and free from germs.

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**x. Water extinguishes burning coal. How can both be used as fuel?**

Water extinguishes burning coal by cooling it below its ignition temperature and cutting off the oxygen supply. However, when steam is passed over red-hot coke (carbon) at very high temperatures, a mixture of gases called Water Gas is produced:



Both carbon monoxide ( $\text{CO}$ ) and hydrogen ( $\text{H}_2$ ) are combustible gases. They burn and release heat energy. So water and coal together produce water gas which can be used as a fuel.

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**xi. What is Eutrophication? How does it pollute water?**

Eutrophication is the excessive and rapid growth of algae and aquatic plants in a water body due to an unusually high concentration of nutrients — especially nitrates and phosphates (from fertilizers and detergents).

When these plants die, bacteria decompose them and in this process consume all the dissolved oxygen in the water. Due to depletion of oxygen, fish and other aquatic animals die. The water becomes green, foul-smelling, and unfit for drinking or any other use.

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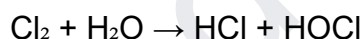
**xii. What are the effects of chemical contamination?**

Chemical contamination of water causes severe damage to health and the environment:

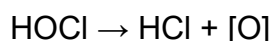
- Heavy metals like mercury, lead, and arsenic cause damage to the nervous system, kidneys and liver. Mercury causes Minamata disease
  - Lead poisoning causes brain damage especially in children
  - Pesticides and herbicides cause cancer, hormonal disorders, and damage the nervous system
  - Industrial chemicals like acids, alkalis and solvents destroy aquatic life
  - Arsenic causes skin diseases and cancer
  - These chemicals accumulate in the food chain (biomagnification) and affect all living organisms
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**xiii. Why does chlorine act as a bleaching agent in the presence of water?**

Chlorine reacts with water to form hydrochloric acid and hypochlorous acid:



Hypochlorous acid (HOCl) is unstable and breaks down to release nascent oxygen [O]:



This nascent oxygen is a powerful oxidizing agent. It destroys the coloring matter (chromophore) in dyes and stains by oxidation, making them colorless. This is how chlorine acts as a bleaching agent.

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#### xiv. What is leachate? How does it get dissolved in water?

Leachate is the contaminated liquid formed when water (rain water or groundwater) percolates through a landfill or solid waste dump. As water passes through the waste, it dissolves soluble chemicals, heavy metals, organic compounds and other harmful substances, carrying them along.

This polluted liquid then seeps into the soil and reaches groundwater or flows into nearby rivers and lakes, contaminating them. Leachate is a major source of groundwater pollution near garbage dumps.

#### xv. What is thermal pollution? How does it affect aquatic life?

Thermal pollution is the rise in temperature of rivers, lakes or oceans caused by the discharge of heated water from industries such as power plants, steel mills and factories, which use water for cooling.

Effects on aquatic life:

- Warm water contains less dissolved oxygen, causing fish and other aquatic animals to suffocate and die
- Most aquatic animals cannot survive above 40°C
- The reproductive cycles of fish are disturbed
- Harmful algae grow faster in warm water, reducing oxygen further
- The natural balance (ecosystem) of the water body is destroyed

### Comprehensive Questions

#### i. Describe the physical properties of water.

1. **Appearance:** Pure water is colorless, odorless and tasteless liquid
2. **Boiling and Freezing Point:** Boiling point = 100°C, Freezing point = 0°C (at 1 atm pressure)
3. **Density:** Maximum density at 4°C = 1 g/cm<sup>3</sup>. Ice is less dense (0.92 g/cm<sup>3</sup>) than liquid water, so it floats
4. **Specific Heat Capacity:** Very high = 4.18 J/g°C. Water can absorb or release large amounts of heat with little temperature change. This stabilizes Earth's climate
5. **Latent Heat of Vaporization:** 44 kJ/mol — very high. Large energy needed to convert water to steam
6. **Latent Heat of Fusion:** 6 kJ/mol — energy needed to melt ice

7. **Hydrogen Bonding:** Strong hydrogen bonds between water molecules are responsible for all unusual properties
  8. **Surface Tension:** Very high surface tension due to hydrogen bonding.  
Insects can walk on water
  9. **Dielectric Constant:** 80 at 18°C — very high, making water an excellent solvent for ionic compounds
  10. **Universal Solvent:** Dissolves more substances than any other known liquid
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### ii. Balanced chemical equations for reactions of water:

- (a) **Potassium (K) with water:**  $2K + 2H_2O \rightarrow 2KOH + H_2\uparrow$  (Reaction is very violent, hydrogen gas burns)
- (b) **Calcium (Ca) with water:**  $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2\uparrow$
- (c) **Zinc (Zn) with steam:**  $Zn + H_2O \text{ (steam)} \rightarrow ZnO + H_2\uparrow$
- (d) **Iron (Fe) with steam:**  $3Fe + 4H_2O \text{ (steam)} \rightarrow Fe_3O_4 + 4H_2\uparrow$
- (e) **Chlorine (Cl<sub>2</sub>) with water:**  $Cl_2 + H_2O \rightarrow HCl + HOCl$
- (f) **Carbon (C) with steam — Water Gas:**  $C + H_2O \text{ (steam)} \rightarrow CO + H_2\uparrow$
- (g) **Sodium oxide (Na<sub>2</sub>O) with water:**  $Na_2O + H_2O \rightarrow 2NaOH$
- (h) **Nitrogen dioxide (NO<sub>2</sub>) with water:**  $3NO_2 + H_2O \rightarrow 2HNO_3 + NO\uparrow$
- (i) **Sodium acetate (CH<sub>3</sub>COONa) with water — hydrolysis:**  $CH_3COONa + H_2O \rightarrow CH_3COOH + NaOH$  (Solution is basic because CH<sub>3</sub>COOH is weak acid and NaOH is strong base)
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### iii. Industrial Wastes and Household Wastes:

**a) Industrial Wastes:** Industries such as textile mills, paper mills, chemical plants, steel factories and tanneries discharge their waste directly into rivers and lakes. This waste contains:

- Heavy metals: mercury, lead, arsenic, cadmium — cause severe poisoning and neurological damage
- Toxic chemicals: acids, alkalis, solvents, dyes — kill aquatic life and make water undrinkable
- Petroleum and oils: form a layer on water surface, blocking oxygen from entering water

- Radioactive waste from nuclear plants contaminates water for thousands of years
- Hot water discharged from cooling systems causes thermal pollution

**b) Household Wastes:** Domestic sewage and household waste is a major source of water pollution:

- Sewage contains human waste full of bacteria, viruses and parasites that cause diseases like cholera, typhoid, dysentery and hepatitis
  - Detergents and soaps contain phosphates that cause eutrophication
  - Garbage dumps near water bodies produce leachate that seeps into groundwater
  - Medicines and chemicals flushed down drains contaminate water supplies
  - Kitchen waste increases the organic load in water, reducing oxygen levels
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#### iv. Effects of water pollutants on life:

##### 1. Effects on Human Health:

- Biological pollutants (bacteria, viruses) cause cholera, typhoid, dysentery, hepatitis
- Heavy metals: mercury causes Minamata disease (neurological disorder); lead damages brain in children; arsenic causes cancer and skin diseases
- Nitrates in drinking water cause a disease called Blue Baby Syndrome in infants
- Pesticides and chemicals cause cancer, liver damage and hormonal disorders

##### 2. Effects on Aquatic Life:

- Reduction of dissolved oxygen (due to eutrophication or thermal pollution) suffocates fish and other aquatic animals
- Heavy metals and chemicals accumulate in fish through biomagnification and eventually reach humans
- Oil spills coat the gills of fish and feathers of birds, causing death
- Acidic water dissolves the shells of aquatic organisms

##### 3. Effects on Agriculture:

- Polluted irrigation water damages crops and reduces yield
- Heavy metals accumulate in soil and enter food chain
- Contaminated water kills beneficial soil microorganisms

#### 4. Effects on Ecosystem:

- Entire food chains are disrupted
  - Loss of biodiversity in water bodies
  - Destruction of coral reefs and wetlands
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#### v. Water is an excellent solvent — how it is beneficial for life but sometimes a nuisance:

**Water as a Universal Solvent:** Water dissolves more substances than any other liquid due to its polar nature, high dielectric constant and hydrogen bonding ability.

##### **Beneficial for Life:**

- All biochemical reactions in the body take place in water as a solvent. Blood, cytoplasm, and digestive juices are all water-based solutions
- Nutrients, minerals and oxygen are dissolved in water and transported throughout the body
- Kidneys dissolve and remove waste products from the body in urine
- Plants absorb minerals from soil only when they are dissolved in water
- Water dissolves  $\text{CO}_2$  and  $\text{O}_2$ , making them available for aquatic plants and animals
- All medicines are designed to dissolve in body fluids (water-based)

##### **Water as a Nuisance (problem):**

- Water dissolves harmful pollutants, chemicals and heavy metals and carries them into drinking water, making it dangerous
- Hard water dissolves calcium and magnesium salts, making it difficult to lather with soap and causing scale buildup in pipes and boilers
- Water dissolves acids from polluted air (acid rain) and damages buildings, metals and crops
- Water dissolves leachate from garbage dumps and contaminates groundwater
- Corrosion of metals and iron rusting occurs because water dissolves oxygen and acts as a medium for the reaction
- Water dissolves salts from soil causing salinization which destroys agricultural land