

Keyterms

- **Alveoli:** Tiny sac like air spaces in the lungs that are separated from the pulmonary capillaries (i.e., tiny vessels that connect the pulmonary veins and arteries and pass through the lungs) by a very thin layer of epithelial cells. They are the functional part of the lungs and act as gas exchange units.
- **Atmosphere:** The mixture of gases extending from the Earth's surface. It is divided into several distinct layers (troposphere, stratosphere, etc.), each separated by a region known as a pause (e.g., the tropopause separates the troposphere and the stratosphere). While each layer can be related to a particular altitude region, the criterion for separation is actually based on temperature variations.
- **Concentrations:** A measure of the amount of a substance within a given volume.

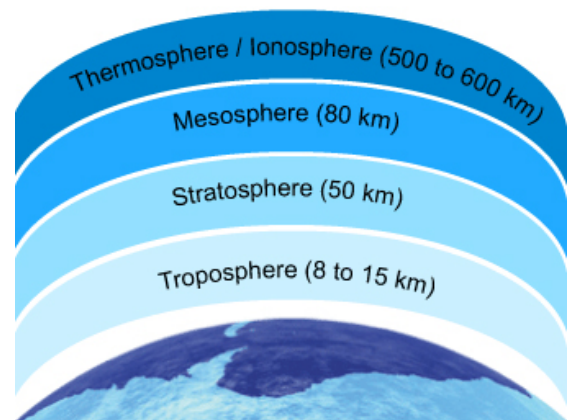
The Air We breath

Air (which all of us must breathe) composes the atmosphere and is a complex mixture of gases surrounding the Earth. The atmosphere is a layered structure divided into layers according to a variety of criteria such as gradually changing:

- Altitude
- Pressure
- Temperature
- Chemical composition and concentration
- Electrical nature

The Atmosphere: According to altitude, the atmosphere is divided into layers:

- **Troposphere:** where all of the weather and clouds which we typically watch and experience are generated and contained.
- **Stratosphere**
- **Ionosphere/Thermosphere**
- **Mesosphere**



Composition of Air: The air we breathe is a mixture of several gases, fine particles and vapors. Dry air consists of 21% oxygen and 78% nitrogen plus traces of other substances that are both natural and human-made.

Major components of air:

- Nitrogen (N₂)
- Oxygen (O₂)
- Water (H₂O)
- Carbon dioxide (CO₂)

Some minor components of air:

- Carbon monoxide (CO)
- Ozone (O₃)
- Oxides of Sulfur (SO_x)
- Oxides of Nitrogen (NO_x)

Air Pollutants: Whereas major components are essential for life, the minor components are pollutants, which under certain conditions may produce adverse environmental and health effects. These air

pollutants are emitted directly into the atmosphere during combustion and production processes, changing the composition of atmosphere and causing poor air quality.

The burning of fossil fuels (i.e., petroleum, natural gas and coal) can be used:

- To generate energy (electricity, gas and steam)
- In transportation (combustion engines)
- In industrial processes that use a great deal of energy sources (i.e., pulp and paper mills, ore smelters, petroleum refineries, power generating stations and incinerators)

These elements are mainly responsible for the presence of minor components. That is, they are the major sources of human-created air pollution.

Air Minor Components:

What is Carbon Monoxide (CO) : When there is an adequate supply of oxygen, there is complete combustion of fossil fuels thereby forming the major by product: carbon dioxide and water CO₂ and H₂O

- Most carbon monoxide CO produced in the process is: immediately oxidized to carbon dioxide
- When there is insufficient supply of oxygen, there is incomplete combustion of fossil fuels and carbon monoxide gas is released
- Carbon monoxide can also be produced by other process:
 - Combustion of organic matter during water incineration
- Natural sources of CO include: forest fires and volcanoes
- When someone inhales CO, it binds the oxygen carrying site on the hemoglobin of red blood cells, causing a reduction of oxygen transport in the body:
 - This is because the hemoglobin can no longer take up oxygen from the air = cell and tissue death
- **Consequently the health effects associated with exposure of CO include**
 - Impaired ability to use oxygen
 - Decreased athletic performance
 - Cardiac Problems

What is Group-Level Ozone: Ozone (O₃) is naturally occurring gas that forms a protective layer in the atmosphere, present predominately in the stratosphere.

- Ozone serves to protect the Earth by absorbing harmful ultraviolet radiation from the sun
- Ground level ozone is produced
 - During photochemical reactions between volatile organic compounds (VOCs) released in automobile exhaust and oxide of nitrogen (NO_x) in the presence of sunlight.
 - In industrial processes such as arc welding
- **Human health effects associated with exposure to ground level ozone include:**
 - Damaged biological tissues and cells
 - Reduced lung function
 - Breathing difficulties
 - Itchy, Burning and water eyes

What are Oxides of Sulfur: Oxides of sulfur (SO_x) are released mainly during processing (smelting) of mineral ores and the combustion of fossil fuels (burning of coal/petroleum)

- Many industrial processes (pulp and paper production and petroleum refining) also generate oxides of sulfur
- Includes: Sulfur dioxide (SO₂) and sulfur trioxide (SO₃)
- Further reactions in the atmosphere may lead to the formation of sulfuric acid (H₂SO₄) and sulfate (SO₄²⁻) salts

- The most common natural source of sulfur dioxide is volcano
- **Human health effects associated with exposure to high levels of oxides of sulfur include:**
 - Problems breathing (particularly for asthmatic people)
 - Respiratory illness

What are Oxides of Nitrogen: Some sources of the emission of oxides of nitrogen (NO_x) include:

- Home
- Industrial use:
 - Manufacture of nitric acid
 - Welding
 - Fuel combustion for transportation (is burnt at high temperatures)
- Mostly in the form of nitric oxide with a small amount of nitrogen dioxide (usually less than 10%)
- Once emitted, nitric oxide (NO) is oxidized, forming nitrogen dioxide (NO_2)
- Nitric acid (HNO_3) and Nitrate (NO_3^-) salts may be formed due to further reactions
- The main oxides of nitrogen present in the atmosphere are nitric oxide (NO), nitrogen dioxide (NO_2) and nitrous oxide (N_2O)
- Nitrogen oxides are also emitted from natural sources including lightning and microbial activity of soil bacteria
- **Human health effects associated with exposure to oxides of nitrogen include:**
 - Serious lung damage
 - Shortness of breath
 - Chest Pain

Assessing Health Risks

Entry into the Body: The air we breath (inhalation) is handled by the lungs, which provide an extremely efficient method of getting oxygen (required for metabolic processes) into and carbon dioxide (waste product of metabolic processes) out of the body.

- Unfortunately, the lungs also provide an excellent opportunity for minor components (pollutants) to diffuse into the blood stream via gas exchange in the alveoli.
- As breathing is a continuous process, considerable amounts of a pollutant (even if present as a minor component) can be inhaled and efficiently transported into the body. Once in the body, they may manifest adverse health effects.

Risk Assessment: In order to assess the health risks due to air pollutants, we require exposure and effects assessment.

- **Exposure assessment:** estimates concentrations using chemical measurements.
- **Effects assessment:** relies on toxicity testing (estimates of exposure toxicity) and computer models to extrapolate data from human population, animal, and bacterial toxicity studies. Quantitative analysis of epidemiological, toxicological and exposure data that are based on the accurate scientific evidence estimates exposure toxicity and risk.

Risk characterization integrates the exposure and effects components to estimate the risk.

Exposure measurement:

Exposure : measured by determining the pollutant concentration in air.

Monitoring methods include:

- Air sampling followed by laboratory analysis of the pollutant(s) using established procedures.
- Real time monitoring using direct reading pollutant-specific monitors.

Commonly used concentration units

For gases and vapors:	For particles:
Parts per million (ppm) Parts per billion (ppb) Percent (%)	Milligrams per cubic meter (mg/m ³) Micrograms per cubic meter (µg/m ³)

Keep in mind:

- 1% = 10⁴ ppm
- 1 ppm = 10³ ppb

Examples:

- A gas is toxic at a concentration of 500. ppm and any level of exposure above this value is considered unsafe for a worker. A real time monitor for the gas indicated a concentration of 0.0615% in a workplace environment. Is it safe to work in such an environment?
 - (0.0615 parts gas/10² parts air) x 10⁶ parts air = 615. ppm
It is not safe to work in such an environment.
Note: x% simply means x parts per hundred parts.
- In an office environment, sampling and subsequent analysis for carbon monoxide (CO) indicated a concentration of 9.0 x 10³ ppb. Express the concentration in the units of ppm and %.
 - 1ppm = 1 x 10³ ppb
(9.0 x 10³ ppb) x (1ppm/1 x10³ ppb) = 9.0 ppm
(9.0 x 10³ parts CO/10⁹ parts air) x 10² parts air = 9.0 x 10⁻⁴%

Threshold Limit Value: Thus, for pollutants, Threshold Limit Values (TLVs) have been developed and issued by the American Conference of Governmental Industrial Hygienists (ACGIH) to assist in the control of workplace health hazards.

- According to ACGIH, Threshold Limit Value-Time-Weighted Average (TLV-TWA), is defined as the time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

Substance	TLV-TWA
CO	25 ppm
NO ₂	3 ppm
O ₃	0.1 ppm
SO ₂	2 ppm

Indoor Air Contamination:

- Air quality problems in many other parts of the world are much worse than in Canada
- This has led to some global concerns about environment
- It is important to note that in addition to the minor components, we are exposed to a large variety of environmental contaminations in industrial, commercial and residential areas
- **Asbestos Fibers:** Asbestos (a mineral fiber) has been used in a variety of building construction materials for insulating and fire proofing

- Deteriorating, damaged, or disturbed insulation, fireproofing : become the source of asbestos fibers in the indoor air
- **Biological contaminants:** Common biological contaminants include:
 - Bacteria
 - Dust mites
 - Insects
 - Mold
 - Pet dander
 - Rodents
 - Viruses
- **Combustion by products:** These includes
 - Gases:
 - Carbon Monoxide
 - Carbon Dioxide
 - Nitrogen Dioxide
 - Unburned Hydrocarbons
 - Small particles: Created by incomplete burning of the fuels
 - Wood
 - Gas
 - Coal
 - Appliances: wood stoves, gas stoves, fireplaces
- **Formaldehyde:** The sources of formaldehyde in indoor air include
 - Pressed wood products
 - Hardwood plywood wall paneling
 - Particleboard
 - Fiberboard
 - Furniture made with the presses wood products
 - Combustion sources
 - Tobacco smoke
 - Textiles
 - Glues
- **Pesticides:** These originate from the products used to kill household pests (insecticides, disinfectants)
 - Pesticides used on lawns and gardens can drift or tracked indoors
- **Radon Gas:** It is slowly released from the ground, water and some building materials that contain very small amounts of uranium:
 - Concrete
 - Bricks
 - Tiles
 - Radon can enter a house through:
 - Cracks in the foundation walls
 - In floor slabs
 - Floor drains
 - Sumps
- **Respirable particles:** Depending upon the size these can be inhaled all the way into the lungs
 - Indoor sources of such particles include:
 - Fireplaces
 - Wood Stoves
 - Oil heater
 - Tobacco smoke

- **Volatile Organic Compound (VOCs)**
 - These compounds originate from a variety of indoor sources:
 - Air fresheners
 - Aerosol sprays
 - Disinfectants
 - Dry Cleaned clothing
 - Hobby Supplies
 - Paints
 - Solvents

Control Strategies:

- Over the past two decades, stricter environmental emission control regulations and pollutant(s) mitigation (reduction) technologies have led to considerable reduction in the concentration of many pollutants.
- The North American Free Trade Agreement (NAFTA) obliges all the three signatories to enforce environmental laws. There is a move in all the three nations toward tougher and thorough reporting of releases of pollutants to the environment. In Canada, National Pollutant Release Inventory (NPRI) is a publicly-accessible database of pollutants released to the Canadian environment.
- Among the global initiatives is the establishment of the International Register of Potentially Toxic Chemicals (IRPTC). It is a computer based database. One of the objectives of the register is to identify the potential hazards of using chemicals and to make people aware of them. The database provides access to information regarding production, distribution, release and disposal of hazardous chemicals. The database also includes information on environmental and health effects of such chemicals.

Air and Water:

Key Terms:

- **Hydrogen bonds:** An interaction, either inter- or intramolecular, between a small, highly electronegative element (N, O, F) that has non-bonded electron pairs (known as a hydrogen bond acceptor) and a hydrogen atom bonded to an electronegative atom (known as a hydrogen bond donor).
- **Electronegativity:** The ability of an atom in a molecule to attract the shared electrons in a covalent bond. The more electronegative an atom is, the larger the attraction for the shared electrons.
- **Dipole:** A pair of electric charges of equal, but opposite, magnitude, separated by a finite distance. Dipoles are characterized by dipole moments, which are a measure of the magnitude of the charge and their intervening separation.
- **Intermolecular attractive forces:** The weak interactions (or forces) that exist between molecules, atoms, or ions. There are several types of intermolecular forces and they are responsible for such properties as melting and boiling points, solubility, surface tension, etc.
- **Solvent:** Any liquid in which another substance (known as a solute) can be dissolved to make a solution. The solute and solvent generally have similar intermolecular properties (e.g., polarity, hydrogen bonding, etc.).
- **Specific heat:** The amount of energy (in the form of heat) needed to raise one gram of a substance by 1°C.
- **Surface tension:** A property that is the result of the uneven distribution of intermolecular forces at the surface of a liquid (i.e., phase interface). These intermolecular forces keep a liquid from immediately overflowing once its height is above the rim of a container and allow for the formation of bubbles. This property is related to the energy required for a substance to overcome the resistance (i.e., attractive intermolecular forces) to an increase in surface area.

- **Capillary action:** A mechanical force that combines surface tension (intermolecular forces between same or like molecules) and adhesion (intermolecular forces between unlike molecules). Adhesion induces an upward force on the surface of a liquid while surface tension holds the surface intact, causing the whole liquid to move up a small tube (capillary).

The Water Molecule: Water (H₂O) consists of two nonmetals hydrogen and oxygen.

- The water molecule is formed by the covalent bonding: of 2 hydrogen atoms to 1 oxygen atom.
- Water is a unique substance that is literally everywhere.
- A vital substance to our well-being and very existence, water is intimately linked to our daily life.

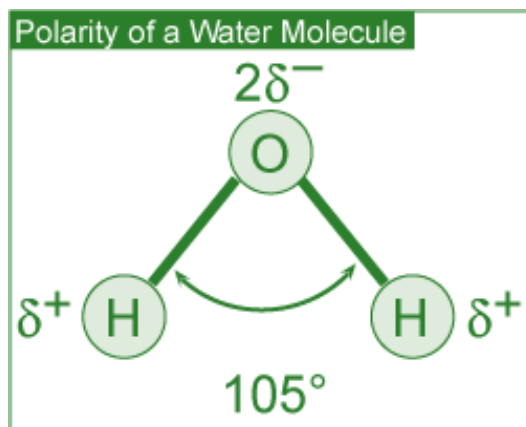
Unique properties of water: The polar nature and the capability to form hydrogen bonds are responsible for many of the unique properties of water. Such properties play an important role in making water essential for life and in determining its chemical behavior in the environment.

We use water for various purposes, such as:

- Cooking and Drinking
- Person Hygiene
- Recreation
- Agriculture
- Transportation
- Energy generation

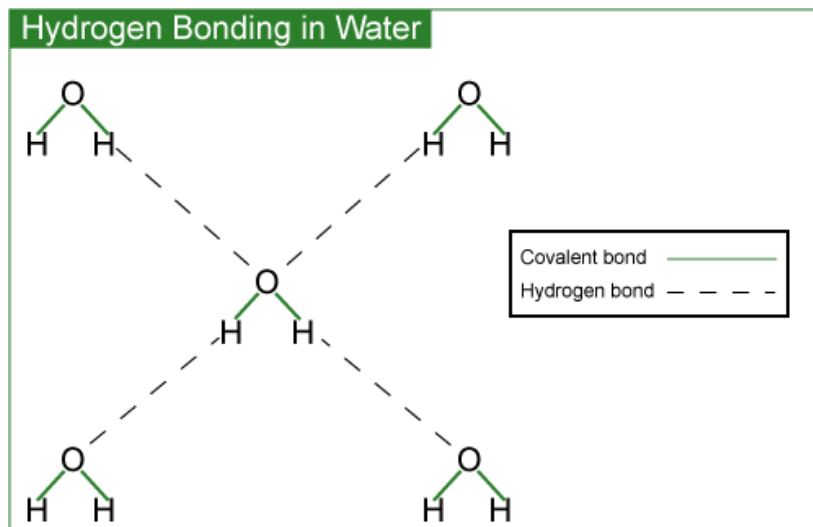
The polar nature of the water molecule is due to its:

- Polar covalent bonds: The electron pair forming the covalent bond (between the oxygen atom and each of the two hydrogen atoms) is more strongly attracted by the oxygen atom due to its higher electronegativity (the ability of an atom in a molecule to attract shared electrons over another atom in the molecule).
- This leads to a partial positive charge on each of the two hydrogen atoms (represented as δ^+) and a partial negative charge on the central oxygen atom (represented as δ^-) making the water molecule behave like a dipole
- Molecular shape: A water molecule has a bent (V-shape) shape (H-O-H bond angle of 104.5°). This, in combination with the polar covalent bonds, leads to a resultant dipole and hence the polarity of the water molecule.



Hydrogen Bonding: The partial charges present lead to intermolecular attraction between water molecules. A single water molecule can thus attract four other water molecules.

- These intermolecular attractive forces are called hydrogen bonds. These are much weaker than the forces holding the atoms in the covalent O-H bond.



Solvent Properties: Water is a powerful solvent due to its high polarity and hydrogen bonding ability.

- It is an excellent solvent for ionic (e.g., table salt), polar covalent (e.g., sugar) and non-polar (e.g., oxygen) compounds. In the case of ionic compounds, the ions are separated from the solid and caged (solvated) by polar water molecules, thus keeping them in solution.
- Polar covalent compounds (i.e., ethanol and glucose) dissolve in water by the formation of hydrogen bonds.
- Water therefore plays an important role in the transportation of nutrients and waste products in biological processes. Aquatic life and plants survive due to dissolved oxygen and carbon dioxide

Thermal Properties: The presence of hydrogen bonds in water accounts for its exceptionally high boiling point, specific heat and heat of vaporization. A portion of the heat supplied is used up in breaking the hydrogen bonds.

- **Specific heat** is defined as the amount of heat energy required to increase the temperature of 1 g of a substance by 1°C.
 - High specific heat of water regulates and stabilizes the temperatures of geographical regions and organisms within a narrow range. This in turn allows our planet to support life.
- **Heat of vaporization** is defined as the quantity of heat required for the conversion of 1 g of a liquid entirely into its vapor at a constant temperature. High heat of vaporization of water helps in regulating the temperature of our body. It is also responsible for powering the winds and storms of our planet.
- Steam and liquid water are 2 different forms of the same chemical substance

Water Density:

Density of Solid and Liquid Water:

- Ice has a hexagonal open structure due to the presence of hydrogen bonds. When ice melts, the open spaces are filled with liquid water, causing the crystal structure to break down.
- This leads to a reduction in volume for the same mass and hence an increase in density (density = mass/volume). The higher density (thus expansion and contraction of volume due to the freeze-thaw cycle) of liquid water than that of ice accounts for phenomena such as:
 - Floating of ice on water
 - Survival of aquatic life during winter
 - Nutrient turnover in bodies of water
 - Formation of pebbles, soil and sand
 - Bursting of frozen water pipe

Surface Properties: The high **surface tension** and capillarity of water is due to the presence of hydrogen bonds. Water is the liquid with the highest surface tension. Plant debris rests (rather than sinks) on the surface of water bodies due to its high surface tension. This provides aquatic life with much-needed shelter and nutrients. **Capillary action** (also due to high surface tension) makes water in soil available to plants.

- **Capillary Effect:** On Earth, the capillary effect can be seen in fine tubes containing liquid: surface tension pulls the liquid column up until there is a sufficient mass of liquid for gravity to overcome the intermolecular forces. As the mass of the liquid column is proportional to the square of the tube's diameter, a narrow tube will draw a liquid column higher than a wide tube. In space, many things work differently, but not always (Length: 9:30, YouTube).
- **Surface Tension :** The Pepper Scatter Experiment: We experiment how a property of water, surface tension actually works

4. Particles of sulfate salts in the atmosphere are generated due to the presence of sulfuric acid.

a) True

6. Which of the following statements is true?

a) The density of ice is higher than that of liquid water

b) Asbestos is a biological contaminant

c) Pesticides originate in the indoor air due to the presence of radon gas

d) Water contains polar covalent bonds

11. Some sources of emission of the oxides of nitrogen include:

a) Welding

b) Burning of coal

c) Microbial activity of soil bacteria

d) All of the answers apply

12. Which of the following statements is true?

a) Water molecules are linear in shape

b) The water molecule behaves like a dipole

c) Ice has a hexagonal closed structure

d) None of the answers apply

13. In a chemical plant four different areas were monitored for the concentration of a toxic chemical X. If the TLV-TWA for the toxic chemical X is 5.0 ppm, which of the four areas is safe for a worker?

a) 1.0×10 ppm

b) 4.0×10^3 ppb

c) $5.0 \times 10^{-3}\%$

d) 7.0×10^0 ppm

11. The process involved in dissolving an ionic compound includes:

a) Separating the ions from the solid

b) Solvating the ions

c) Keeping them in solution

d) All of the answers apply

17. The reactions of the oxides of nitrogen in the atmosphere lead to the formation of:

a) Phosphoric acid

- b) Sulfuric acid
- c) Hydrochloric acid
- d) Nitric acid**