Moisture in the Atmosphere

June 28rd, 2021

Moisture in the Atmosphere

The fourth element of weather and climate

TABLE 3-1 The Elements and Controls of Weather and Climate

Elements of Weather and Climate	Controls of Weather and Climate
Temperature	Latitude
Pressure	Distribution of land and water
Wind	General circulation of the atmosphere
Moisture content	General circulation of the oceans
	Altitude
	Topographic barriers
	Storms

The Impact of Atmospheric Moisture on the Landscape

When the atmosphere contains enough moisture, water vapor may condense to form haze, fog, clouds, rain, sleet, hail, or snow, producing a skyscape that is **both visible and tangible**

Precipitation produces dramatic short-term changes in the landscape whenever **rain puddles form, streams and rivers flood, or snow and ice blanket** the ground.

The presence or absence of precipitation is critical to the survival of almost all forms of terrestrial vegetation.

Let’s talk about water…..

WHAT IS PECULIAR ABOUT MOISTURE?

Nature of Water

Has no substitute….

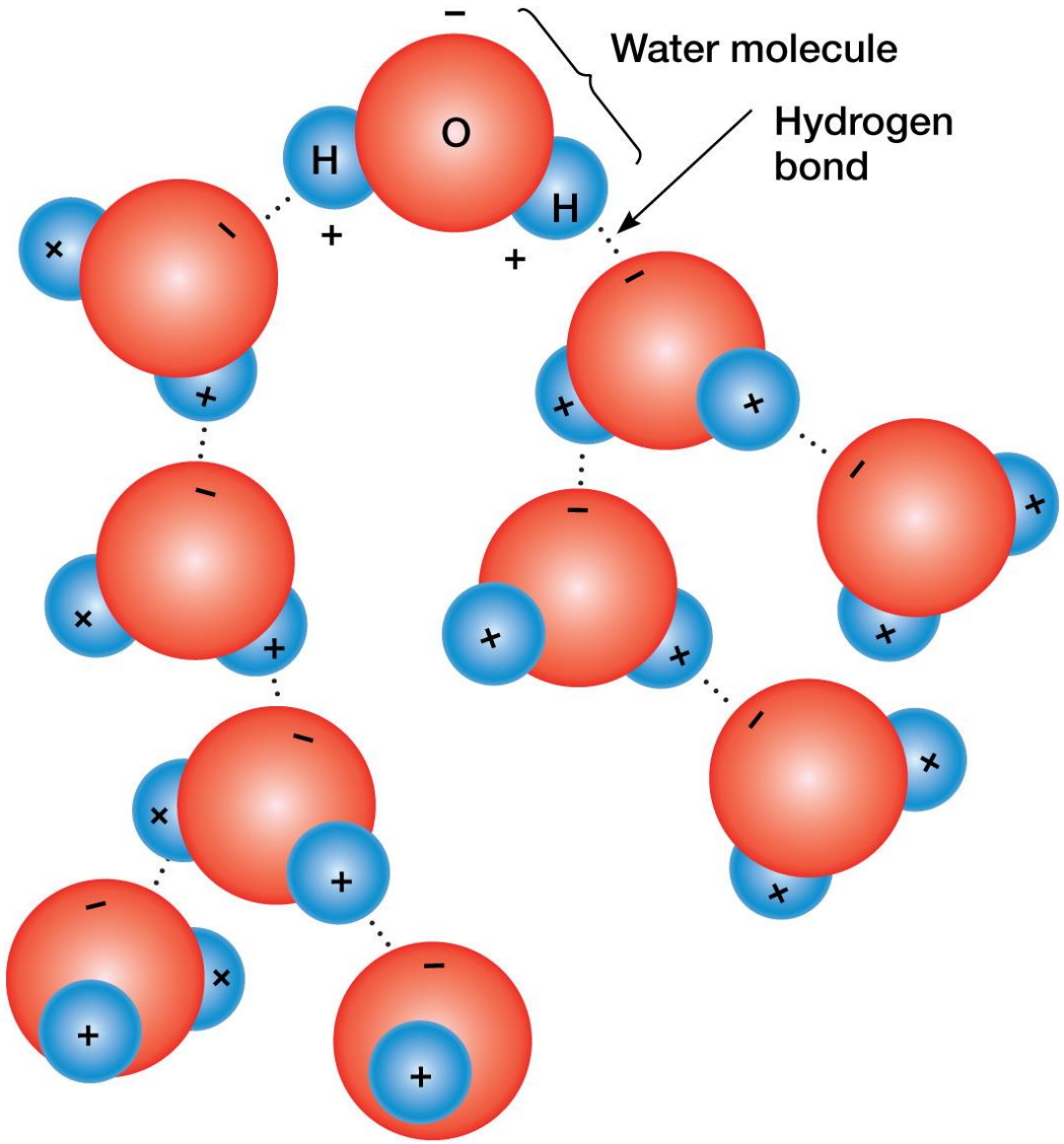
Occupies 71% of the Earth's surface, but less than 2% is freshwater and available for human needs

Pure water has no color, taste or smell

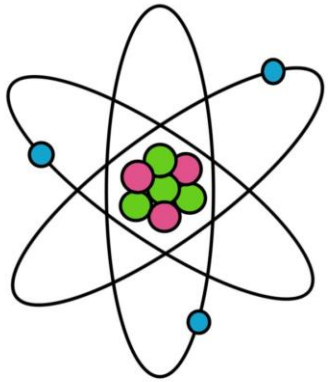
It turns to solid at 0°C (32° F)and boils at 100°C(212°F) at sea level

Chemistry of Water

•Hydrogen bonds form between water molecules because the **negatively charged oxygen side** of one molecule is attracted to the **positively charged hydrogen side** of another molecule.



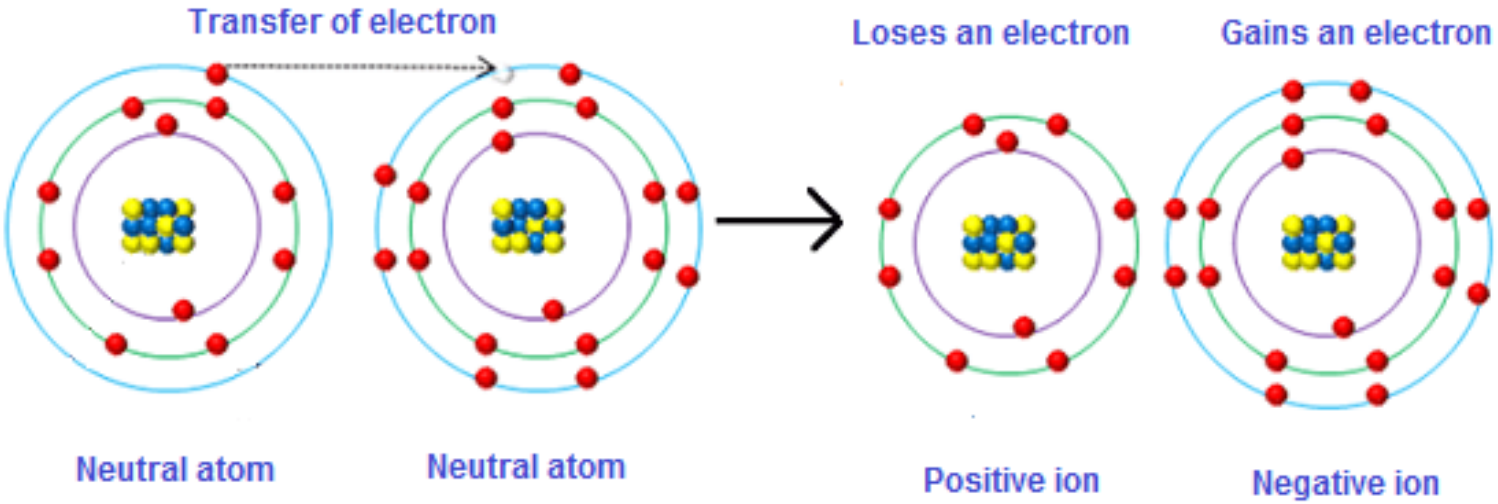
Parts of an Atom



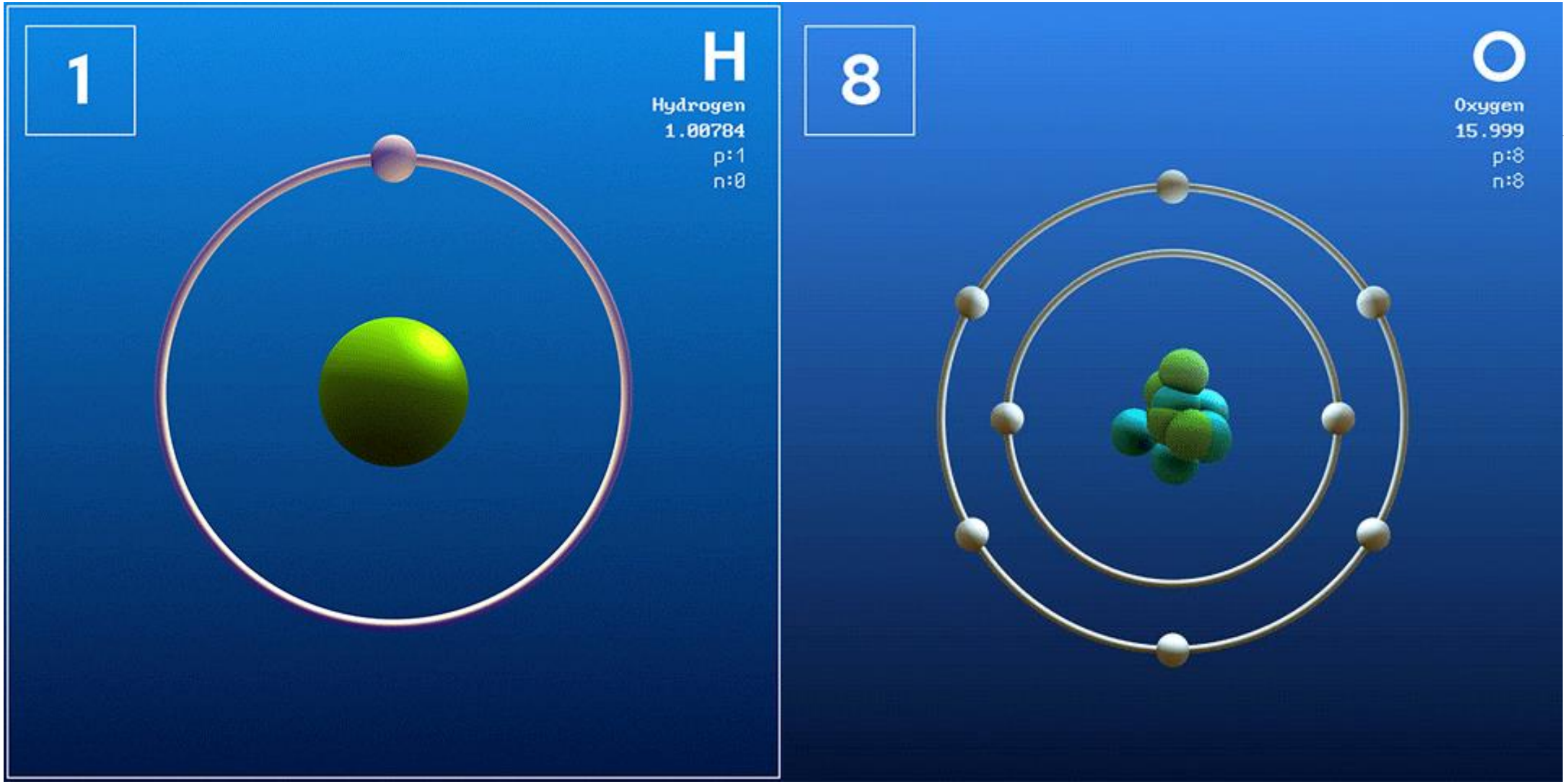
NEUTRON
no charge
part of the nucleus

PROTON
positively charged
part of the nucleus

ELECTRON
negatively charged
surround the nucleus

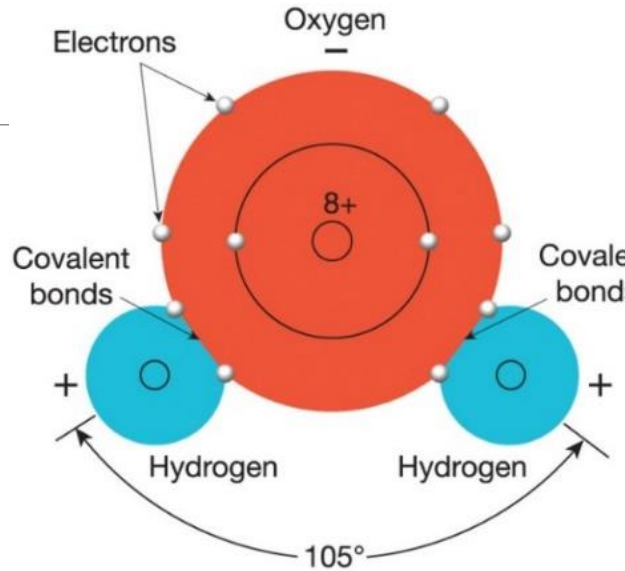


Physics and Radio-Electronics

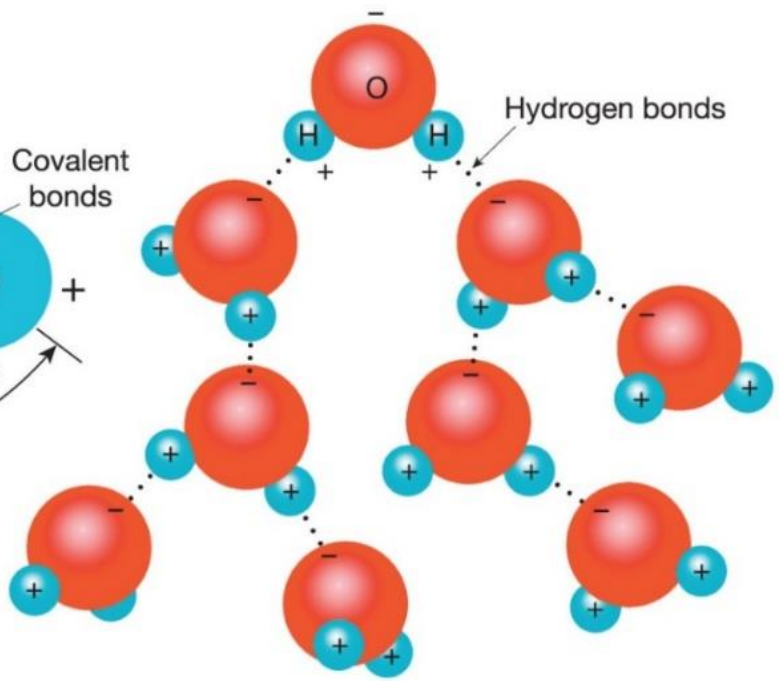

1
H
Hydrogen
1.00784
p:1
n:0
8
O
Oxygen
15.999
p:8
n:8

Chemistry of water

- Atoms and molecules
- Two hydrogen and one oxygen molecule (H_2O)
- **Covalent bonds**
  - *Water molecules possess a polarity with the oxygen side being negative and the hydrogen side being positive.*
  - Water molecules link together through their hydrogen bonds.



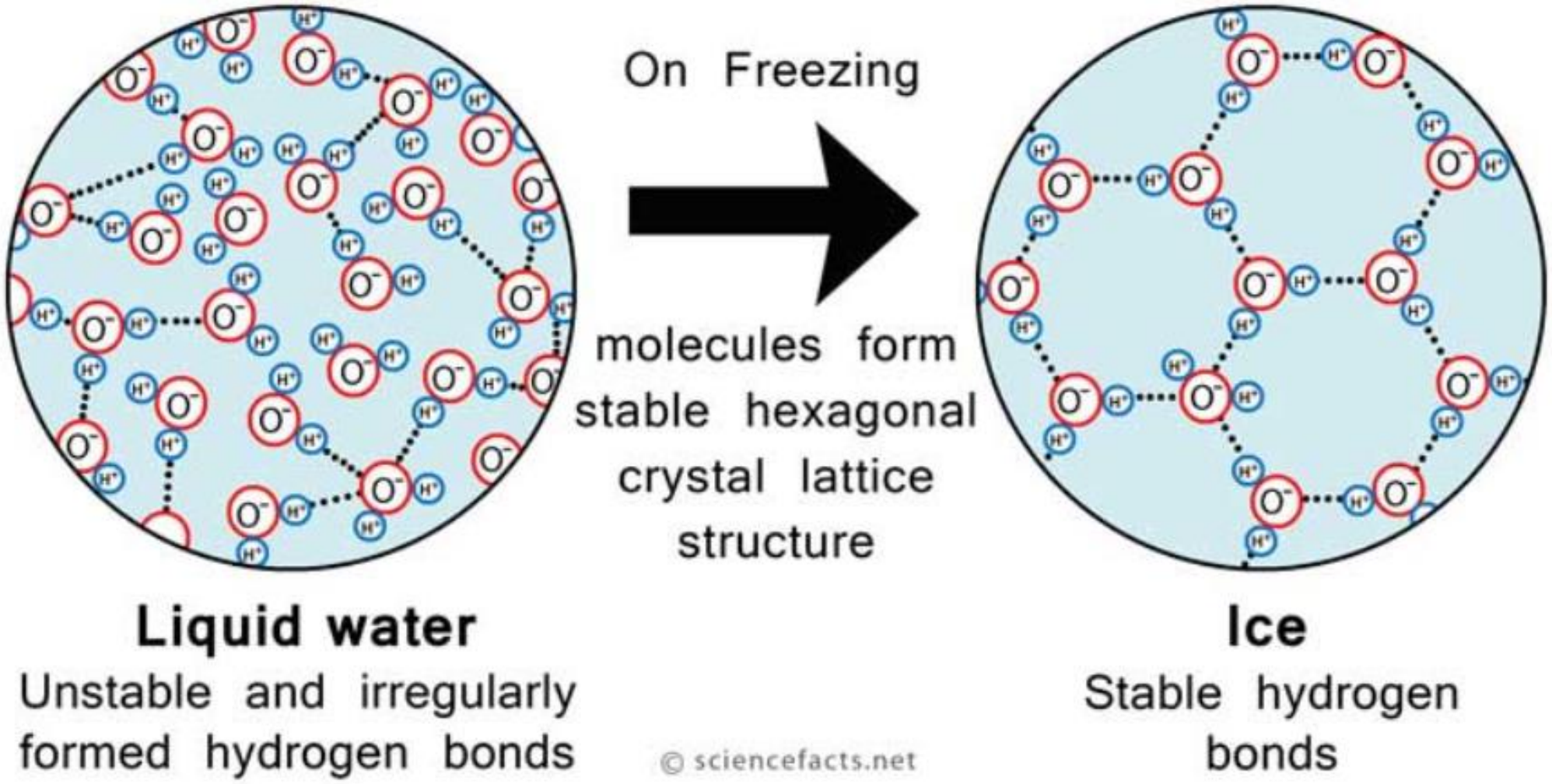
(a) The oxygen side of the water molecule has a slight negative charge, and the hydrogen side has a slight positive charge.



(b) Hydrogen bonds form between water molecules because the negatively charged oxygen side of one molecule is attracted to the positively charged hydrogen side of another molecule.

Properties of Water

- **Liquidity**—water is abundant in liquid form on numerous locations on Earth's surface.
  - This property increases its versatility in the atmosphere, lithosphere and biosphere.
- **Ice Expansion**—as water freezes, it contracts until it reaches about 4° C and then expands (as much as 9%) as it cools from 4° C to 0° C.
  - As it cools and freezes, water begins to form hexagonal structures held together by hydrogen bonding.
  - This expansion also allows ice to become less dense than liquid water and float.


On Freezing
molecules form stable hexagonal crystal lattice structure
Liquid water
Unstable and irregularly formed hydrogen bonds
© sciencefacts.net
Ice
Stable hydrogen bonds

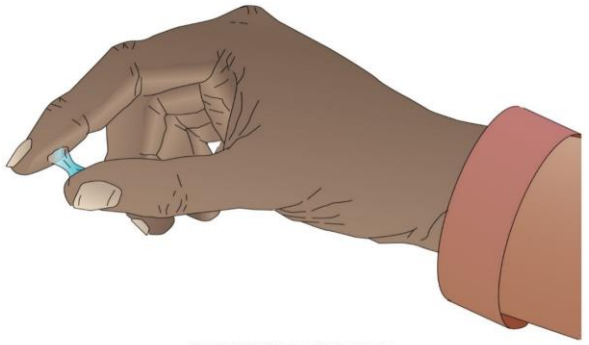
Properties of Water

•**Solvent ability**—water is also a "universal solvent" in that it can dissolve almost anything.

•**Surface tension**: A steady-handed person can hold a drop of water between two fingers because the **attraction (electrical polarity)** of one water molecule for another provides the water with strong surface tension – **sticky property (adhesion and cohesion)**

•**Capillarity – surface tension and adhesion combined allow water to climb upward in narrow openings** (plant roots for instance) in an action called *capillarity*

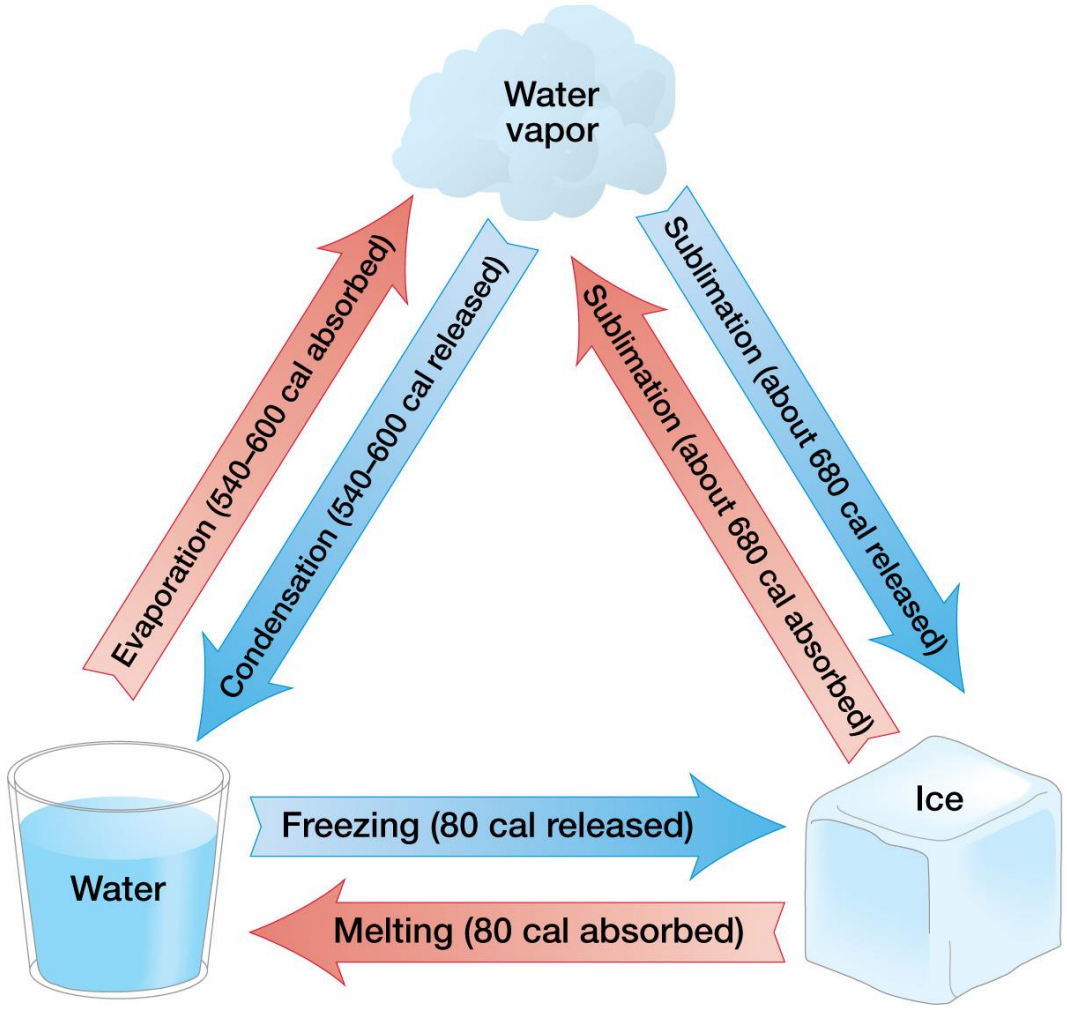
- Water can also stick to many surfaces (adhesion)
- Great heat capacity – absorb enormous amounts of heat



Phases of Water

(a) Temperature below freezing, water exists in a solid state - ice.
(b) Temperature above freezing, water may exist as familiar liquid state.
(c) Moisture also exists in the gaseous state as water vapor. Water vapor is invisible, as indicated by the empty area between the tip of the spout and the beginning of the steam cloud.

The heat of the stove causes the liquid water in the kettle to boil and become water vapor. This vapor issues from the spout and quickly cools back into tiny liquid drops that we see as the steam cloud.



The arrows indicate gain or loss of latent heat (measurements are in calories)

The Hydrologic Cycle

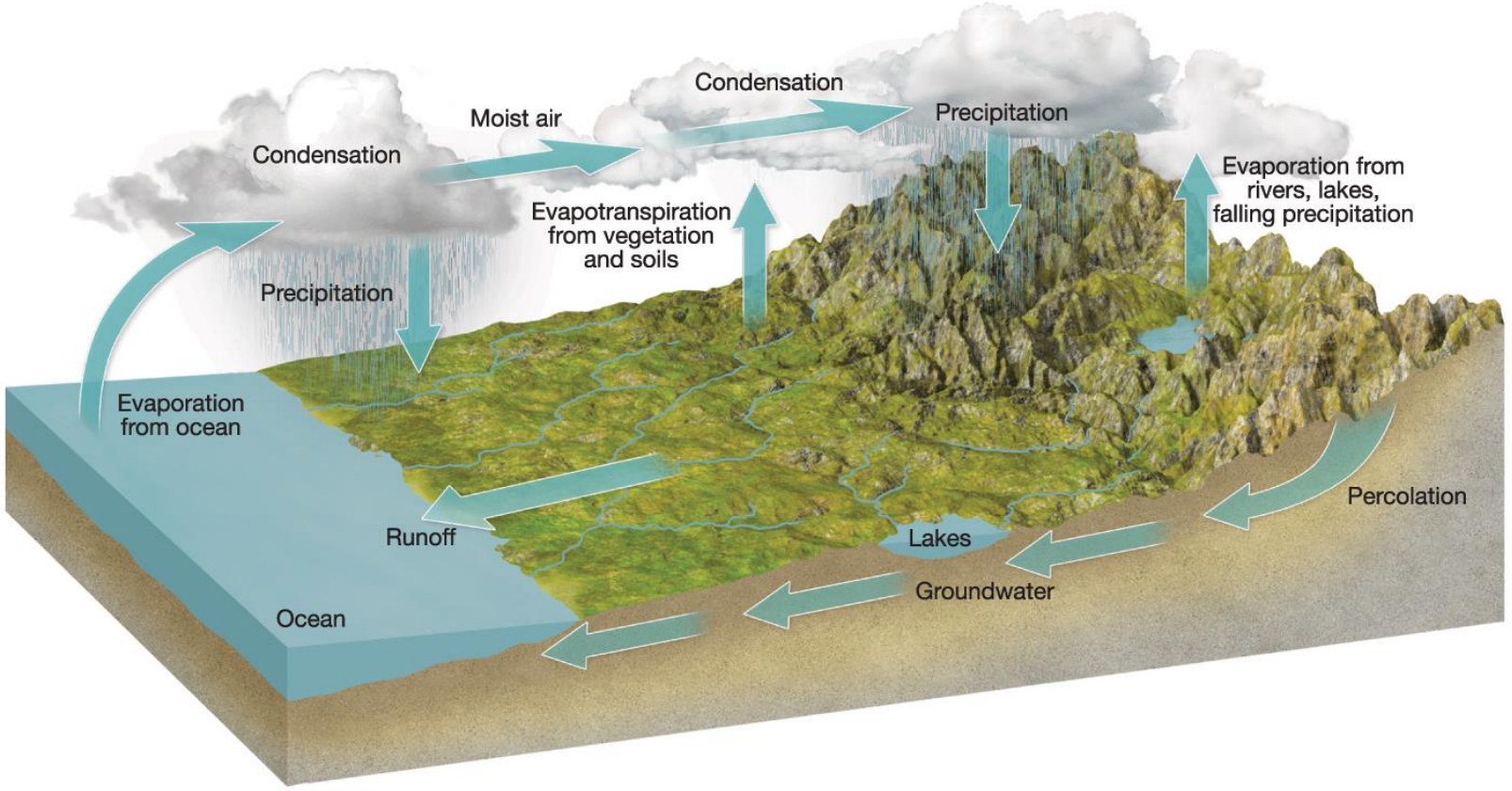
Transfer of water between oceans, land surface water systems, ground water systems, and through the atmosphere

The widespread distribution of water vapor in the atmosphere reflects the ease with which **moisture can change from one state to another at the pressures and temperatures** found in the lower troposphere.

Moisture can leave as gas and return as liquid or solid

The Hydrologic Cycle

- That ceaseless interchange of moisture from one physical state to another: Liquid Water evaporates > Water Vapor in the atmosphere > Saturation > Condensed > Liquid or Solid > Returns to Earth as Precipitation > Evaporation and Evapotranspiration continues the cycle
- The movement of moisture through the cycle is intricately related to many atmospheric phenomena and is an important determinant of climate because of its role in rainfall distribution and temperature modification.



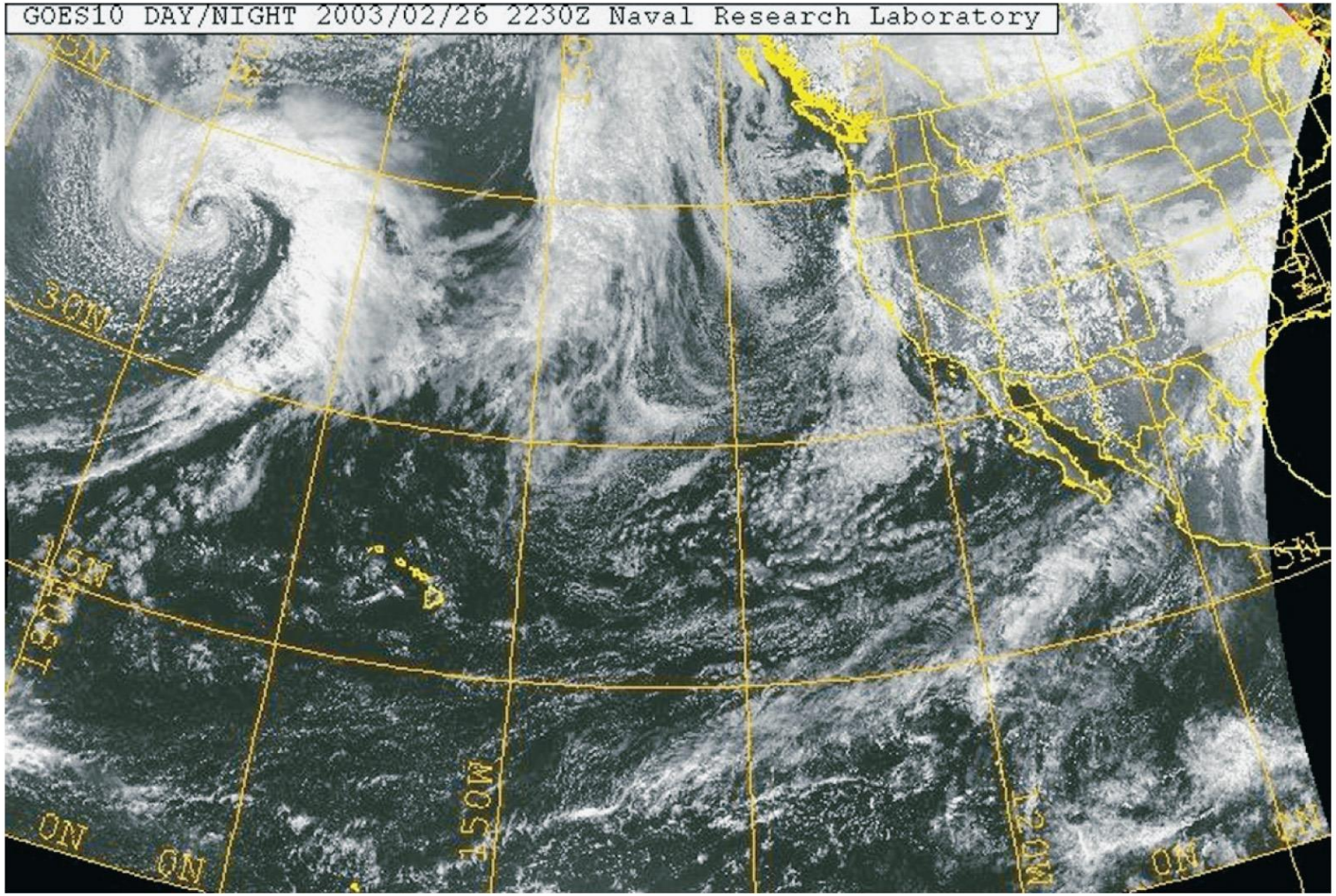
Phase Changes

Evaporation – liquid water converted to the gaseous form.
Condensation – water vapor converted to the liquid form
Sublimation—the process by which water vapor is converted directly to ice, or vice versa.
When we go from one phase to another, this is called a ***phase change***
Phase changes of water are accompanied by the exchange of latent heat.

Importance of latent heat in the atmosphere—the absorption and release of energy during evaporation and condensation have several effects.

- **Water can store energy when it evaporates.**
- **Water can release heat back to the atmosphere when it condenses.**

- The phase we are often most concerned about in the study of the atmosphere is the vapor as this leads to precipitation



Evaporation and Rates of Evaporation

Changes easily from one state to another with temperature and pressure changes.

- This ease of change results in erratic distribution around the world.

Molecules of water escape the liquid surface into the surrounding air.

Water vapor is added to the air when the rate of evaporation exceeds the rate of **condensation—*net evaporation***, in this instance.

Rate of evaporation from a water surface depends on three factors:

- The temperature of the water and the air;
- the amount of water vapor already in the air;
- whether the air is still moving.

Evaporation and Rates of Evaporation

1. Temperature is a key factor in evaporation, both in water and in the air around it.
   - Molecules become more agitated the higher the temperature, and this agitation leads to evaporation.
2. Temperature works in conjunction with pressure.
   - **Vapor pressure**—the pressure exerted by water vapor in the air.
   - At any given temperature, there is a maximum vapor pressure that water vapor molecules can exert.

Saturated air—the point at which some water vapor molecules must become liquid because maximum vapor pressure is exceeded.

- The warmer the air, the more water vapor it can hold before becoming saturated.

Evapotranspiration

Evapotranspiration—the process of water vapor entering the air from land sources.

- **Evapotranspiration occurs through two ways:**
  - **Transpiration**—the process by which plant leaves give up their moisture to the atmosphere;
  - **Evaporation -** from soil and plants.
  - Most evapotranspiration occurs through plants.

Potential evapotranspiration—the maximum amount of moisture that could be lost from soil and vegetation if the ground were sopping wet all the time.

- Potential evapotranspiration rate and actual rate of precipitation play a key role in determining a region's groundwater supply (or lack of it).

What is humidity?

Humidity

The amount of water vapor in the air

Measures of Humidity

Actual Humidity: how much water vapor is present in the air. Measured in (**Units**): $g/m^{3)}$

Specific Humidity: the mass of water vapor in a given mass of air. Measured in g/kg.

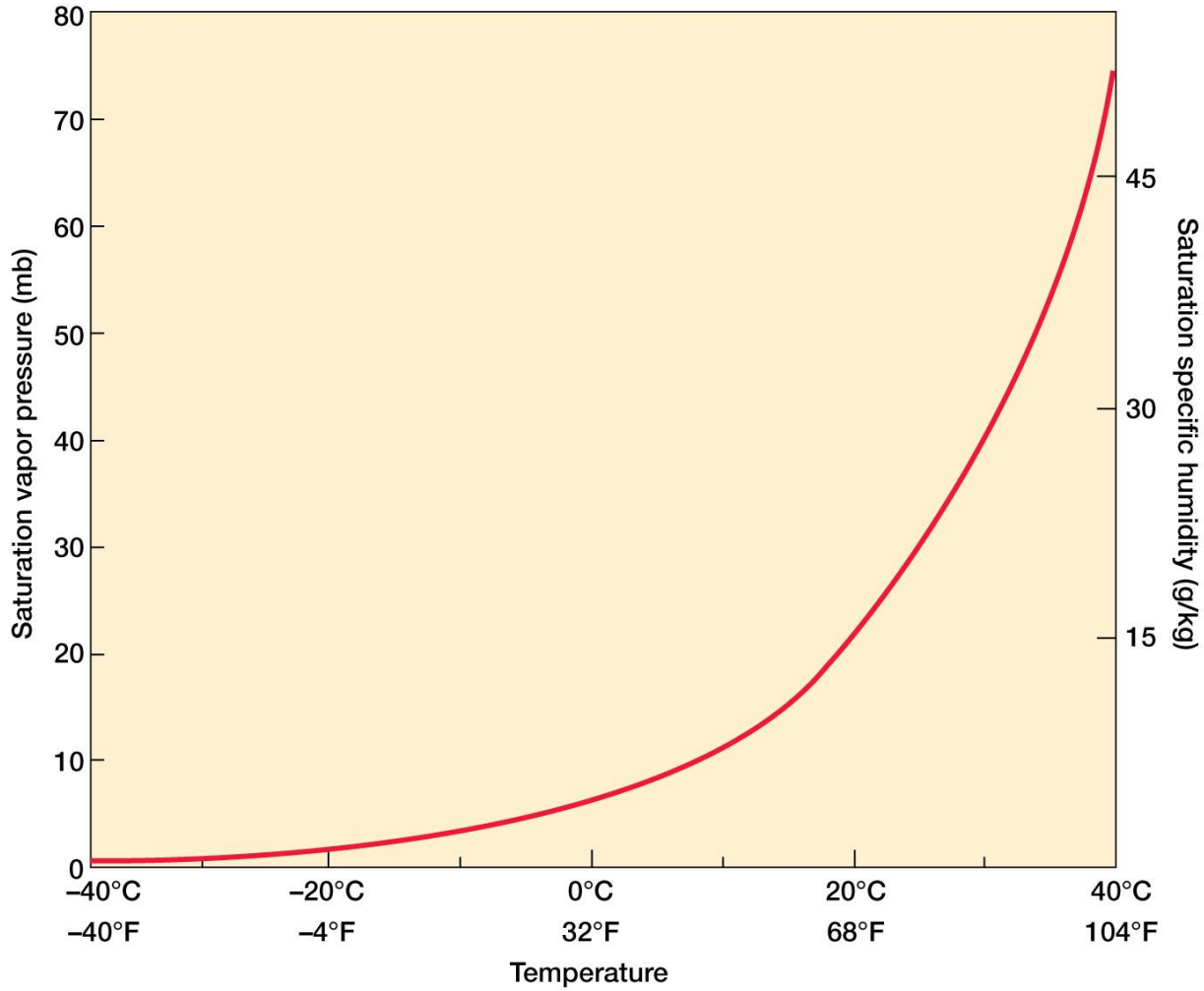
Saturation Humidity – *the amount of water vapor a parcel of air could hold at a particular temperature*. For any given parcel of air, we could **measure its *temperature* and get an idea of how much moisture it could hold**. Measured in (**Units**): $g/m^{3)}$

Related Humidity Concepts

Vapor pressure — the contribution of water vapor to the total pressure of the atmosphere.

- At any given temperature, there is a maximum vapor pressure that water vapor molecules can exert.

Saturation vapor pressure — the maximum possible vapor pressure at a given temperature.



As temperature increases, the water vapor capacity of the air increases (or **the warmer air is, the more vapor it can hold**).

Measures of Humidity

Relative humidity—*an expression of the amount of water vapor in the air in comparison with the total amount that could be there if the air were saturated*. This is a ratio that is expressed as a percentage

- Relative Humidity = Actual Humidity (Actual water vapor in air)/Saturation Humidity (capacity) x 100
- **Relative humidity changes if either the water vapor content or the water vapor capacity of the air changes.**

Temperature–Relative Humidity Relationship

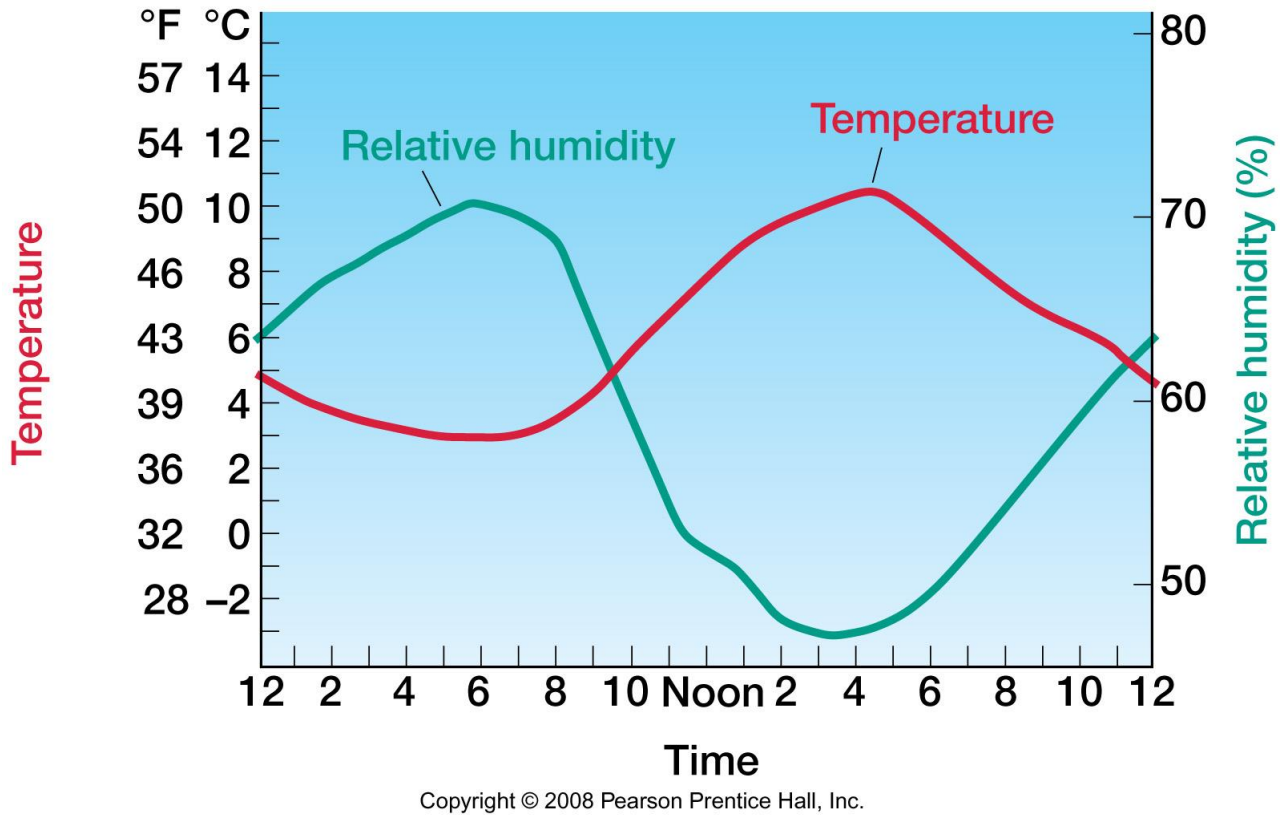
Relative humidity also changes if temperature changes.

Relationship between temperature and relative humidity is one of most important in all meteorology.

Inverse relationship—as one increases, the other decreases.

- Relative humidity can be determined through the use of a hygrometer (**psychrometer**)

Relationship Between Air Temperature and Humidity



As the temperature rises, the relative humidity decreases. Thus, relative humidity tends to be lowest in midafternoon and highest just before dawn

Related Humidity Concepts

Dew Point Temperature—the critical **air temperature** at which saturation is reached.

- Cooling is the most common way that air is brought to the point of saturation and condensation.
- **Dew point temperature is critical in understanding precipitation.**
- Actual humidity = Saturation Humidity (Relative Humidity = 100%)

Saturated air

The point at which some **water vapor molecules must become liquid because maximum vapor pressure** is exceeded.

The warmer the air, the more water vapor it can hold before becoming saturated.

But see supersaturation = air contains more water vapor than is needed to cause saturation.

Related Humidity Concepts

Sensible temperature—a concept of the relative temperature that is sensed by a person's body.

- The temperature as it feels to a person's body
- Involves not only actual air temperature, but also other atmospheric conditions, particularly relative humidity and wind, that influence our perception of warmth and cold.

On a warm, humid day, the air seems hotter than the thermometer indicates, and the **sensible temperature is said to be high**

- This is because the air is near saturation, and so moisture on the human skin does not evaporate readily.
- Thus there is little evaporative cooling and the air seems warmer than it actually is.

On a warm, dry day, evaporative cooling is effective, and thus the air seems cooler than it actually is; in this case **the sensible temperature is low**

Related Humidity Concepts

On a cold, humid day, the coldness seems more piercing because body heat is conducted away more rapidly in damp air; **the sensible heat is again described as low**

On a cold, dry day, body heat is not conducted away as fast. The temperature seems warmer than it actually is, and we say that the sensible temperature is relatively high

Wind movement also affects sensible temperature influencing evaporation and convection of heat away from the body

Important Due Dates:

Quiz 8: 06/28/2021 by 11:59 PM

Exam 2: 07/03/2021 by 11:59 PM

- Covers everything from 06/07/2021 to 06/28/2021 (Today's lecture included)
- 25 questions – 40 minutes
  - 21 Multiple choice
  - 1 matching
  - 3 short answers (one line)
- Each question worth 4 points, total 100 points
- Password will be given in class

Exercise 5: 06/30/2021 by 10:00 AM