

Properties of the Solar System

Disk shape of the solar system:

Planets orbit the sun in nearly the same plane
(Solar System forms a disk).

All planets orbit the sun in the same direction.

Most rotate in the same sense as they revolve about
the sun.

Two types of planets:

Terrestrial (Earthlike) Planets

Giant (Jovian) Planets

Small Bodies:

Asteroids:

Small rocky bodies.

Most orbit the sun between the orbits of Mars and
Jupiter in the *asteroid belt*.

Comets:

“Dirty Snowballs”

Most exist in the outer reaches of the solar system.

Oort Cloud—Spherical cloud of comets extending
halfway to the nearest stars.

Kuiper Belt—objects beyond the orbit of Neptune.

When they approach the sun the ices boil off and are
blown away from the sun forming the comet’s tail.

Formation of the Solar System

Any theory of the formation of the Solar System
must be able to explain its general properties.

Two Types of Theories:

Catastrophic theories:

A star collided with the sun throwing out material
which eventually formed the planets.

Prediction:

Solar Nebula Theory:

Planets formed along with the sun from gas and dust
which surrounded the sun as it formed.

It is thought that the Solar System formed from a cloud of dust and gas about 4.5 billion years ago.

Cloud collapses under its own gravity.

The central region collapses to form the sun.

As the cloud collapses its spin rate increases.

Due to the spin, the gas and dust bulge out forming a disk of material around the forming sun.

Condensation

As the disk starts to cool off, the gas starts to condense.

Metals (e.g. iron) condense at the highest temperatures.

Rocky materials condense at somewhat lower temperatures.

Volatile materials (such as water, carbon dioxide, nitrogen) only condense at low temperatures.

Temperatures in the disk near the forming sun are the highest and fall off away from the center:

Near the forming sun we would expect what materials to condense out?

Little further out we would expect what to condense out?

Even further out?

Accretion

Grains of material grow by condensation as gas molecules condense onto the grains

Eventually (sizes of a few centimeters), the growth by condensation becomes inefficient.

Large number of grains are formed by condensation.

These will continually collide with each other.

Some of them will stick together thus growing larger in a process called accretion.

This process of accretion continues until the grains grow to sizes of about 1 to 100 kilometers.

At this point they are known as planetesimals.

As the planetesimals grow, gravity starts to become important and helps to keep the planetesimals together.

Eventually, a few bodies become large enough to grab other particles by their own gravity.

At this point a runaway process occurs—these particles grow bigger—> more gravity—>grow even more quickly...

These bodies eventually become the planets in our Solar System.

Near the end of the formation of the planets, a period of heavy bombardment occurs as the planets sweep up any remaining debris in the Solar System.

It is during this period, about 4 to 4.5 billion years ago, that most of the craters seen on planetary surfaces were formed.

Gravitational Collapse

If a proto-planet grows large enough, its gravity will become strong enough to pull gas from the nebula (mostly hydrogen and helium) onto itself.

This process is called gravitational collapse.

This process occurred for the Jovian planets but not the terrestrial planets for two reasons:

Predictions of the Solar Nebula Theory:

The sun and planets are formed at the same time from a large cloud of dust gas.

Predicts what relation should hold between the ages of the planets and the sun?

What about the catastrophic theory?

If the solar nebula theory is correct young stars should be surrounded by clouds of gas and dust.

What prediction does the solar nebula theory make about the abundance of planetary systems?

Meteorology

Study of the atmosphere, weather, and climate.

Composition of the atmosphere:

78% Nitrogen

21% Oxygen

0.93% Argon

Traces of other constituents.

While important for our livelihood, the major components play little role in our weather.

Variable components play the major role here:

Water vapor—varies from essentially zero to ~4%

Responsible for cloud formation and precipitation on the Earth.

Like CO₂ it is a greenhouse gas—important role in heating of the atmosphere.

Certainly important to our comfort:

Aerosols—

Play an important role in cloud formation.

Can absorb and scatter light—

variations in dust content explains much of the variation in the colors of our sunsets and rises.

Ozone (O₃)

Ozone is formed high in the Earth's atmosphere.

Good absorber of UV radiation.

Protects us from harmful UV radiation which would otherwise reach the surface of the Earth.

Structure of the Atmosphere

Atmospheric pressure at sea level is 14.7lb/in²

This is simply the weight of all the molecules in the atmosphere above a given area.

What happens to the pressure as we go up in elevation?

Why does the atmosphere have this structure?

Why is the troposphere so much more turbulent than the stratosphere and other layers?

What drives the winds we see on the planet?

To answer these questions, we must examine how the atmosphere is heated and how energy is transferred to, from, and within the atmosphere.

Heat Transfer

Place two objects at different temperatures together and what happens?

Heat can be transferred by three major mechanisms:

1. Conduction

The ability of substances to conduct heat varies considerably from material to material.

On a hot day would you be more nervous about sitting on a metal or wood chair?

Would you prefer to stick your hand in boiling water (212°F) or a 400°F oven?

2. Convection

In convection heat is transferred by the motion of a mass or substance from one place to another.

Hot material moves to a colder region and vice versa.

Examples?

Most of the heat energy transferred within the atmosphere is transferred through convection.

3. Radiation

The final mechanism by which objects may exchange heat is through the exchange of electromagnetic radiation.

What is electromagnetic radiation? Examples?

They vary in their *wavelength*.

Altogether they form the electromagnetic spectrum.

Important mechanism because it is the only mechanism effective in the vacuum of space.

All objects radiate energy.

Not just hot objects, even you are emitting radiation at this moment.

Do you think that hotter objects emit more or less light than cool objects? Examples?

The peak wavelength of intensity also depends on the temperature:

As a body is heated, the peak intensity occurs at shorter (more energetic) wavelengths.

The wavelength at which an object radiates most of its energy is inversely proportional to its temperature (Wien's Law):

$$\text{Wavelength} = 3,000,000\text{nm}/T(\text{K}).$$

The sun (6000K) emits most of its light at around what wavelength?

A cool star (say 3000K)?

You (310K)?

Good emitters of radiation are also good absorbers.

Solids and liquids emit and absorb light at all wavelengths.

Gases are selective emitters and absorbers of light.

They are nearly transparent to some wavelengths

Opaque to others:

How does all this affect the Earth's atmosphere?

Almost all of the energy which heats the atmosphere comes from the sun.

What happens to this radiation when it arrives?

Temperature Measurements

The temperature at the surface of the planet varies substantially.

Polar regions are cold; tropics are warm.

Much of the variation can be explained by seasonal variations and the fact that less direct sunlight reaches high latitudes.

But not all.

What other factors play a role?

Moisture

While a minor constituent of the atmosphere, water plays an important role in our weather.

Why (and how) does it condense to form clouds?

What causes it to rain?

Its presence even makes the air less stable.

To answer these questions we need to examine what happens when water changes state.

Change of State

Under normal conditions (i.e. situations we see on Earth) matter exists in three states:

Solid

Liquid

Gas

Humidity

Even below the boiling point, some water will be present as water vapor.

We can see this by considering an example:

A jar filled with water and dry air.

What happens?

What if we increased the temperature?

What if we lowered the temperature?

If a parcel of air has reached this equilibrium point it is said to be saturated.

Is air always saturated?

Relative humidity is the ratio of the air's actual water content to its maximum capacity at saturation.

Suppose we have a parcel of air that is not saturated—what would happen to the relative humidity if we were to lower its temperature?

What if we were to raise the temperature?

Temperature at which the relative humidity would be 100% is called the *dew point*.

What would happen if the temperature were reduced below this temperature?