# Geosci 232 Problem Set 2
# Fall Quarter 2007

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*Getting basic data on planets* The module `planets.py` contains a convenient handbook of basic data on Solar system planets and selected moons. If you `import planets`, then, for example, `planets.Earth.a` is Earth's radius in meters, and `planets.Earth.g` is Earth's acceleration of gravity. For more information about what data is in a `Planet` object, type `help(planets.Planet)`. Most basic planet data can also be easily found via a Web search, or on Wikipedia.

## 2 Problems

**Problem 2.1** *Making the Earth's Oxygen*

Photosynthesis performs a kind of solar-powered electrolysis, taking water ($H_2O$) and carbon dioxide ($CO_2$) and using them to make organic matter– where the carbon and hydrogen and some of the oxygen go – and releasing the rest of the oxygen in the process. For the purposes of this problem, you can consider an organic molecule to be $CH_2O$, though real organics are typically more complex. The Earth's atmosphere contains about 20% $O_2$ (molar), and the oxygen can be considered well-mixed out to a great altitude.

Consider a patch of ocean of some surface area $A$. How deep a layer of water needs to be converted by photosynthesis to create the oxygen in the air above that patch? How many moles of organic matter will be made in the process? How many kilograms?

**Problem 2.2** The temperature of Titan's troposphere, which contains most of the mass of the atmosphere, is about 100K. The atmosphere is mostly

$N_2$. Estimate the density scale height of Titan's atmosphere and compare it to Titan's radius. How does the situation on Titan differ from that of Earth? For which body is the atmosphere more accurately described as a "thin spherical shell"?

**Problem 2.3** *An atmosphere for the Moon*

At some time in the future the surface of the Earth becomes uninhabitable, and the few remaining residents decide to move to the Moon. To make life more congenial, they decide to give the Moon an $N_2/O_2$ atmosphere with a surface pressure of 1 bar. They also add in enough carbon dioxide to bring the mean surface temperature up to $280K$. How much total mass needs to be brought in to create this atmosphere? If the mass comes in the form of comets, each 10km in radius, how many are needed? Estimate the scale height of the atmosphere, and compare it to the radius of the Moon.

*Python Tips:* The radius of the moon is `planets.Moon.a`, and the acceleration of gravity at the surface of the Moon is `planets.Moon.g`.

**Problem 2.4** *Evaporating a methane lake on Titan*

Titan receives somewhat less than $5W/m^2$ of sunlight at its surface. If all of this energy were used to evaporate methane, about how long would it take to evaporate a lake of methane with a depth of 1 meter?

*Python Tips:* The latent heat of evaporation of methane is given in `phys.CH4.L_vaporization`.

**Problem 2.5** *Clausius-Clapeyron: CO2 condensation on Snowball Earth*

According to some interpretations of geologic data from the Neoproterozoic (about 600 million years ago), the Earth went through one or more episodes of global glaciation. The phenomenon is known as "Snowball Earth." The general thinking has it that the Earth would exit from a snowball state after sufficient $CO_2$ has built up in the atmosphere to warm the planet to the point where it deglaciates.

In the Snowball state, the planet becomes very cold, because an ice surface reflects a great deal of solar radiation. Simulations show that the surface temperature at the Winter pole can drop to 160K, though it warms to about 240K in the balmy polar summer. Under these circumstances, how high would the $CO_2$ partial pressure have to rise before $CO_2$ condensation sets in at the winter polar surface? Based on a 1 bar surface pressure for the non-$CO_2$ part of the air what would the molar mixing ratio and molar concentration of $CO_2$ have to be to cause condensation? How do your answers change if the surface temperature is increased to $200K$? What do you think condensation would do to the global $CO_2$ concentration?