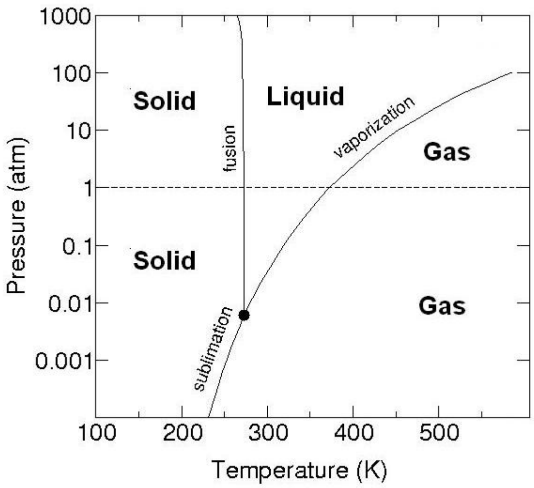
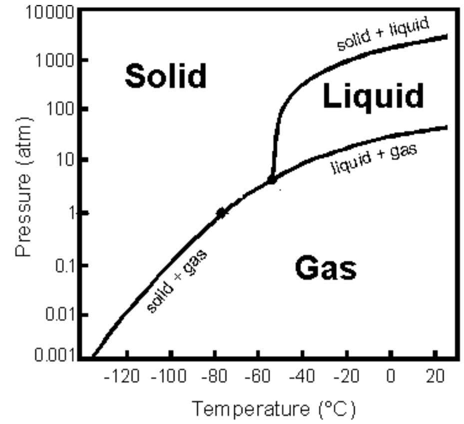
What is a Snowball's Chance on Mars?



The H_2O Phase Diagram



The CO_2 Phase Diagram

These diagrams above are called **phase diagrams**. The one to the left shows all of the phases for matter for water as you change the temperature and pressure of the water in your sample. A pressure of 1.0 'atmospheres' is what we experience at sea level. This equals 14 pounds/inch^2 (or in metric units about 100 kiloPascals). As you move horizontally across the diagram towards increasing temperatures (measured in Kelvin units) at a constant pressure of 1.0 atm, the state of your water will change from solid ice, to liquid water at 273 Kelvin, to water vapor at 373 Kelvin.

Snow balls require that you create some liquid water by compressing the snow crystals so that they can glue together as the water refreezes. This will happen along the curve marked 'fusion' which is the boundary between the solid ice and liquid water phases.

The diagram to the right shows all of the phases for carbon dioxide as you change its pressure and temperature. For convenience we use the Celsius temperature scale. Note that 0^o Celsius = +273 on the Kelvin scale, and that a difference of 1^o C equals a change by 1 K on the Kelvin scale.

Problem 1 - We can make snow balls because the pressure (close to 1.0 atm) we apply with our hands at the ambient temperature (close to 273 K) is just enough to melt the ice into water and refreeze it to form a glue holding the snowflakes together. The temperature in Antarctica is typically 250 K. Can you make snowballs in Antarctica with normal hand pressure?

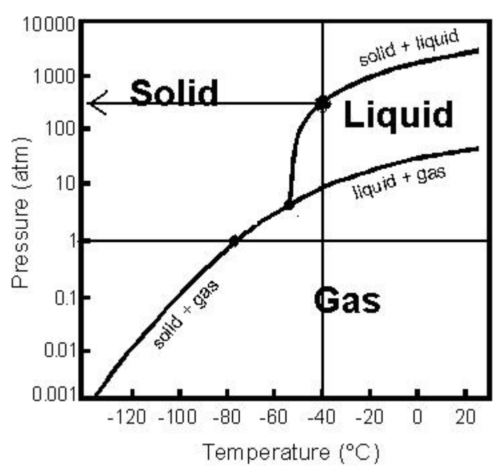
Problem 2 - On Mars, the majority of the ice is carbon dioxide ice. To make a carbon dioxide snowball, imagine applying 1 atm of hand pressure. The average temperature where the carbon dioxide snow falls is about -40^o Celsius in the daytime. Use the phase diagrams to explain why making a showball on Mars may be difficult or easy?

Problem 1 - We can make snow balls because the pressure (close to 1.0 atm) we apply at the ambient temperature (close to 273 K) is just enough to melt the ice into water and refreeze it to form a glue holding the snowflakes together. The temperature in Antarctica is typically 250 K. Can you make snowballs in Antarctica with normal hand pressure?

Answer - At normal winter temperatures near 273 K (0^{o}C) and 1 atm, the diagram shows that we are very, very close to the conditions needed to make solid ice turn to liquid water with a bit of extra pressure. The vertical line, which represents the ice to liquid transition crosses a pressure of 1 atm at a temperature of just +0.010 C! The diagram also shows that at 250 K (-17^{o}C) we are far to the left of the vertical line where solid ice can turn to liquid. At this temperature, we will need hand pressures higher that 1000 atm to make snowballs! So you can not make snowballs in Antarctica.

Problem 2 - On Mars, the majority of the ice is carbon dioxide ice. To make a carbon dioxide snowball, imagine applying 1 atm of hand pressure. The average temperature where the carbon dioxide snow falls is about -40^{o} Celsius in the daytime. Use the phase diagrams to explain why making a showball on Mars may be difficult or easy?

Answer: The main ingredient for a snowball on Mars would be carbon dioxide. The figure below shows the horizontal line representing a hand pressure of 1.0 atm and the vertical line representing the temperature of -40^{o} C on Mars where snowfall might occur.



The temperature is -40 C, so draw a vertical line on the CO_2 phase diagram until it intersects the solid+liquid line. This is where CO_2 can be in both the solid and liquid phases. You need the liquid CO_2 to supply the glue to hold the solid snowflakes together in the CO_2 snowball. But if you draw a horizontal line to the left, you will see that for you to get this liquid+solid phase at this temperature, you need a pressure of over 100 atmospheres. That about 1500 pounds per square inch of hand pressure, which will be impossible for you to achieve!

This diagram also shows that, on Earth, where the atmospheric pressure is 1 atmosphere, if you move from right to left along the 'pressure = 1 atm' line, a solid piece of CO_2 that you buy at the store will immediately start evaporating into the gas phase. Only if you could freeze this 'dry ice' below -80 C will it stop evaporating into a gas phase (called sublimation) and remain a stable solid.