

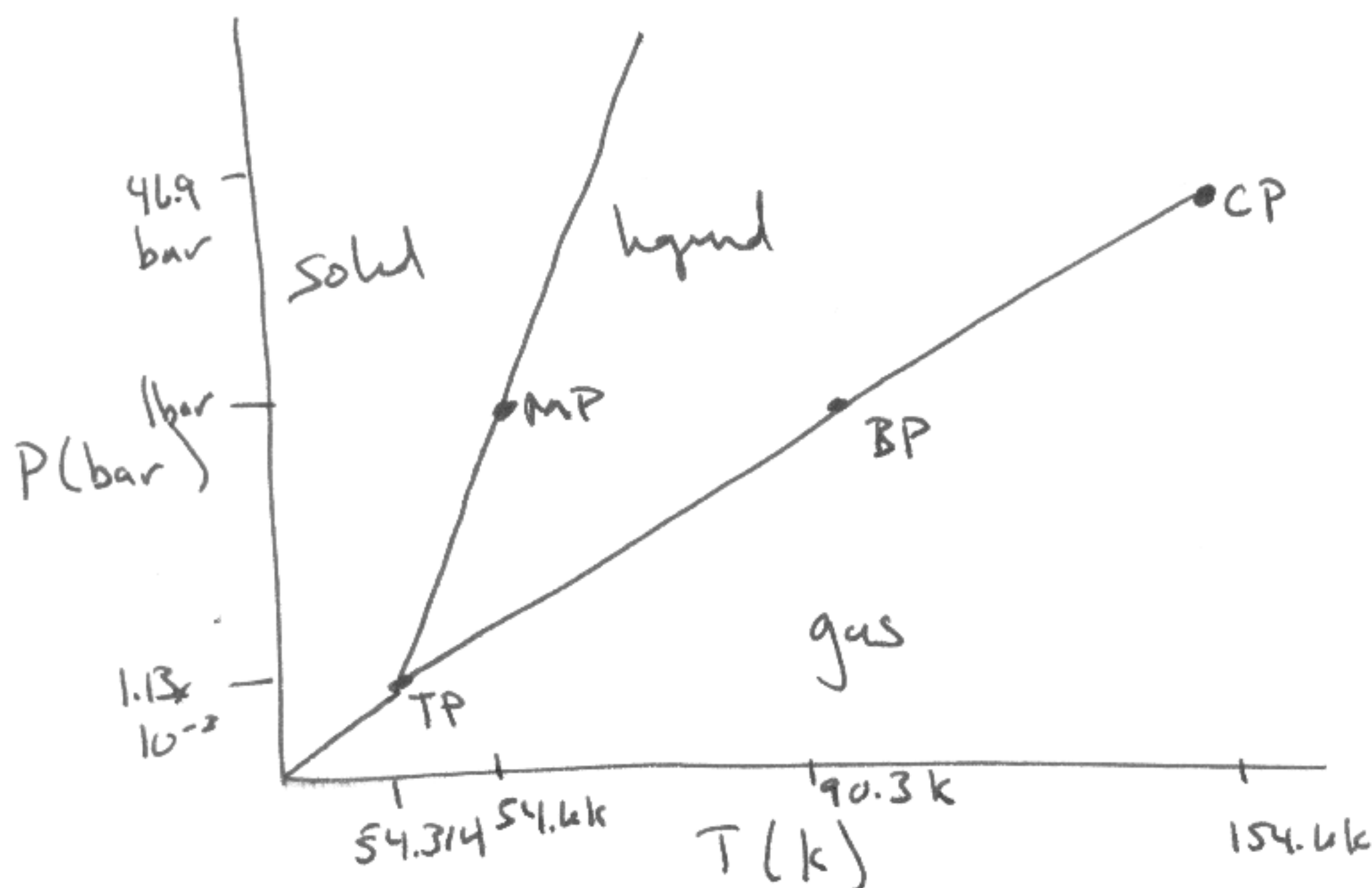
HW14 Key

1. O_2 : $TP = 54.3\text{K}, 1.129 \times 10^{-3}\text{ bar}$

$CP = 154.6\text{K}, 42.86\text{ bar}$

$T_{bp} = -182.9^\circ\text{C} @ 1\text{ bar} = 90.1\text{K}$

$T_{mp} = -218.4^\circ\text{C} @ 1\text{ bar} = 54.6\text{K}$

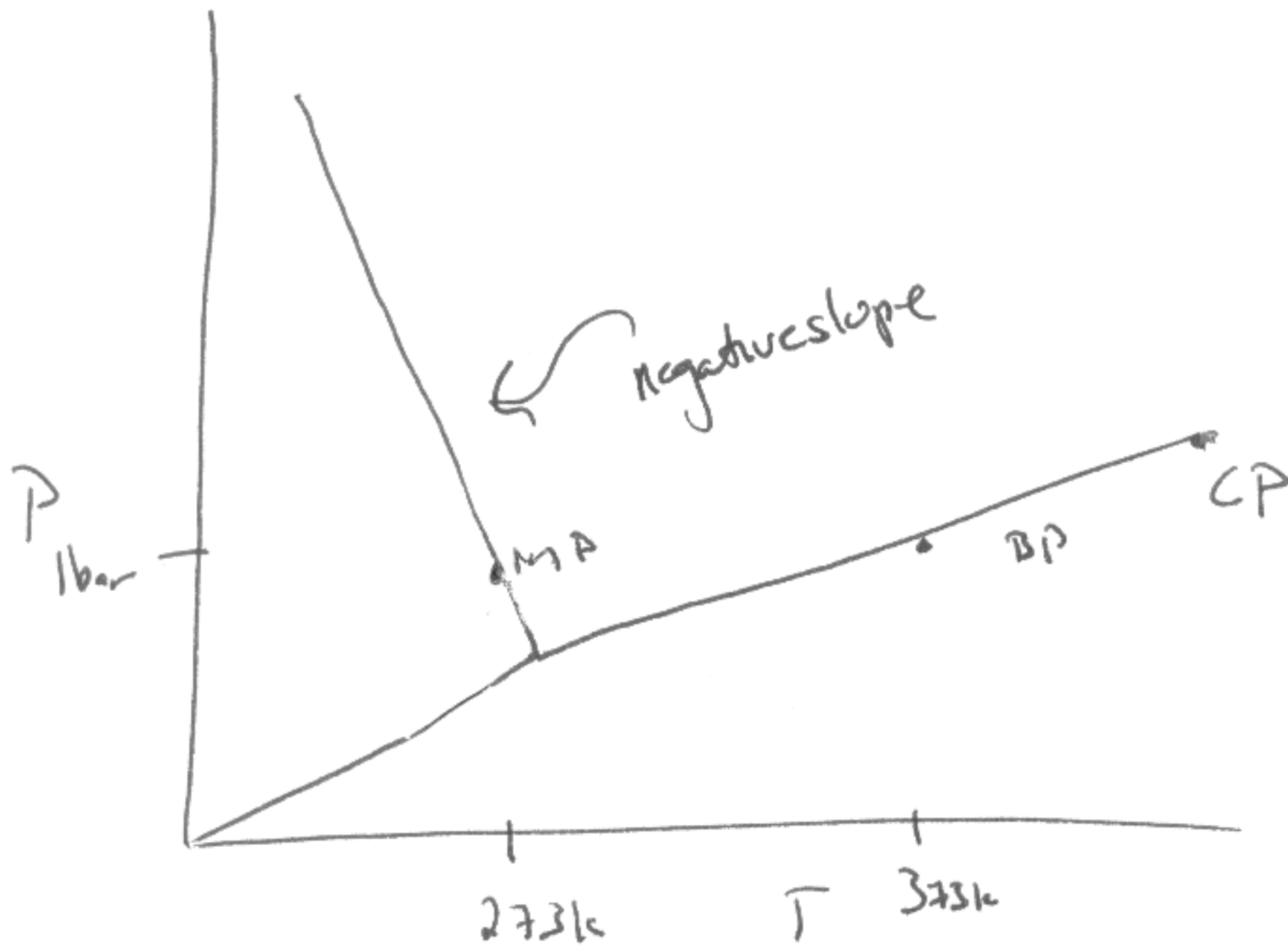


(obviously not to scale)

The melting point occurs at higher T and P than the TP (triple point), so the slope between them must be > 0 . Between these two points, solid O_2 does not melt as pressure increases. We have no information about the slope of the line above the melting point, although I have drawn a curve with a positive slope.

2. H₂O: at 1 bar, ^{BP} ~~BP~~ = 373K
 MP = 273K

(2)



3.

$$\frac{\Delta P}{\Delta T} = \frac{\Delta H_{\text{trans}}}{T_{\text{trans}} \Delta V_{\text{trans}}}$$

$$\rho(\text{ice}) = 0.92 \text{ g/cm}^3 \left(\frac{100 \text{ cm}}{1 \text{ m}} \right)^3 \left(\frac{1}{18 \text{ g/mol}} \right) = 5.0 \times 10^4 \text{ mol/m}^3$$

$$\rho(\text{water}) = 1.0 \text{ g/mL} \left(\frac{1000 \text{ mL}}{1 \text{ L}} \right) \left(\frac{1 \text{ L}}{0.001 \text{ m}^3} \right) \left(\frac{1}{18 \text{ g/mol}} \right) = \frac{1.0 \times 10^6 \text{ g/m}^3}{18 \text{ g/mol}} = 5.6 \times 10^4 \frac{\text{mol}}{\text{m}^3}$$

$$\Delta V = V_L - V_S = \frac{1}{\rho_L} - \frac{1}{\rho_S} = -2.0 \times 10^{-6} \text{ m}^3/\text{mol}$$

$$\Delta P = P_f - P(\text{atm}) = \frac{\Delta H_{\text{trans}}}{T_{\text{trans}} \Delta V_{\text{trans}}} ; \quad P_f = \frac{\Delta H_{\text{trans}}}{T_{\text{trans}} \Delta V_{\text{trans}}} + P_{\text{atm}}$$

$$P_f = \frac{(6010 \text{ J/mol})(-0.1 \text{ K})}{(273 \text{ K})(-2.0 \times 10^{-6} \text{ m}^3/\text{mol})} + 1.01 \times 10^5 \text{ Pa}$$

$$P_f = 1.20 \times 10^6 \text{ Pa}$$

this is the pressure the skater must apply to melt the ice.

(3)

$$\text{Pressure actually exerted by skater} = \frac{F}{A} = \frac{(70 \text{ kg})(10 \text{ N/kg})}{(0.3 \text{ m})(0.003 \text{ m})}$$

$$P_{\text{skate}} = 7.8 \times 10^5 \text{ Pa}$$

- off by a factor of ~ 2 , so this force will not melt the ice.

$$P(\text{needed}) = \frac{F}{A} = \frac{(\text{mass})(10 \text{ N/kg})}{A} = 1.2 \times 10^6 \text{ Pa}$$

$$\text{mass} = \frac{P(\text{Area})}{10 \text{ N/kg}} = \frac{(1.2 \times 10^6 \text{ Pa})(0.3 \text{ m})(0.003 \text{ m})}{10 \text{ N/kg}}$$

$$\text{mass} = 108 \text{ kg}$$

Ice at 273 K and 1 atm is near its triple point, where solid, liquid, and gas all coexist. Solid ice under these conditions always has a thin film of water covering it. This is also why you will slip on ice, even without skates on.

4.

The triple point of any substance is the pressure and temperature in which all three phases (solid, liquid and gas) are in equilibrium. The earth's average temperature and pressure is very close to the triple point temperature and pressure of water. Given this information, it is not surprising that water can be found in all three phases at the earth's surface. Vast amounts of the earth's surface are covered by liquid water in the form of oceans, lakes, rivers and streams. Gaseous water is found just above the surface in the air. Solid water in the form of ice is found at the poles. Additionally, the presence of water in all three phases at temperatures and pressures near its triple point, allows water to help regulate the temperature and pressure of the earth. The water will change phase due to small changes in temperature and pressure absorbing or releasing heat during the transformation. The vast amounts of liquid and solid water would also be able to store heat even without a phase change. For example, a lake is able to absorb radiant heat from the sun during the day and release the heat at night regulating the temperature of the surrounding area.

On Titan the average temperature is near the triple point temperature of methane suggesting methane plays an important role in the regulation of the climate on Titan. This suggests that methane on Titan is most likely also present in its solid and liquid forms and that the equilibrium between these forms can respond to slight changes in temperature and pressure.

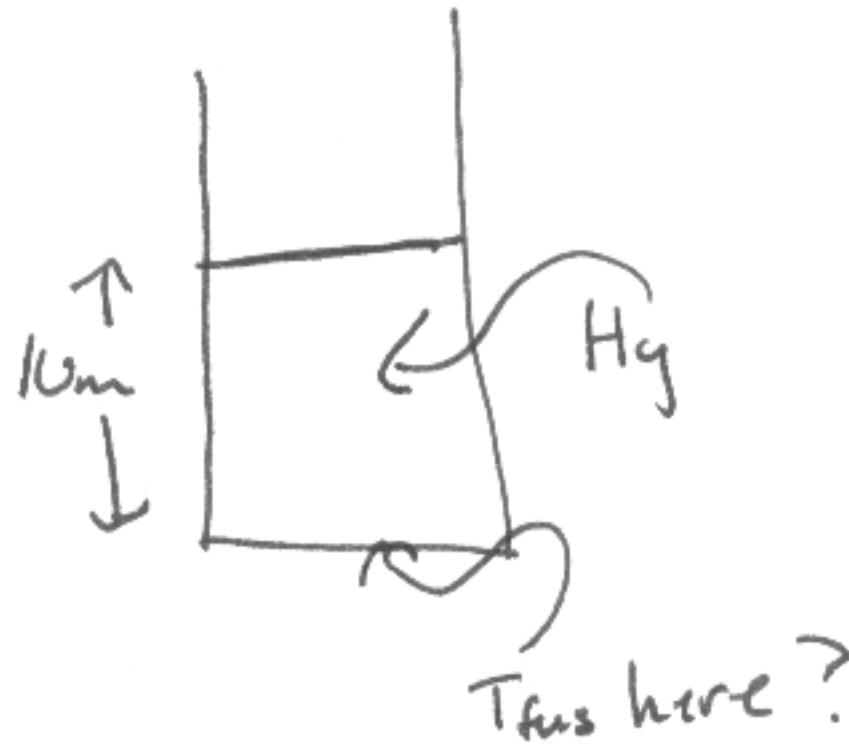
5. $\Delta H_{fus}(\text{Hg}) = 2.92 \text{ kJ/mol}$

$T_{fus} = 234.3 \text{ K}$

$\Delta V_{fus} = 0.517 \text{ cm}^3/\text{mol}$

$\rho = 13.6 \text{ g/cm}^3$

$h = 10.0 \text{ m}$



$$\Delta T = \frac{T_{fus} \Delta V_{fus} \Delta P}{\Delta H_{fus}} \quad ; \quad \Delta P = P_{bottom} - P_{top} = \rho gh$$

$\Delta T = 0.071 \text{ K}$

6. Looking at Fig. 10.17, the vapor pressure of water at 90°C is $\sim 0.70 \text{ atm}$. That means that only 70% of the earth's atmosphere is above the camp, so 30% is below.

7. Water molecules make H-bonds between the H on one water and a lone pair on another water. Because of water's tetrahedral geometry, these H-bonds are directional. In the solid phase, a specific lone pair points to a specific H atom, but in the liquid phase, with molecules in constant motion, an H-atom can move between the lone pairs of a particular water molecule w/ low energy.

This motion is halted in the solid, and H atoms are now pointed at specific lone pairs. This will push waters away from each other, resulting in a situation where water occupies a higher volume, i.e. has lower density, in solid vs. liquid.