Physics I

Latent Heat

Problem 1.- A 10-gram bullet made from an alloy is found to have melted on impact with an armored truck. Assuming the bullet was fired at room temperature (20º C) estimate the minimum muzzle velocity of the bullet.

Recall that kinetic energy is $KE = \frac{1}{2}mv^2$

Specific heat capacity of the alloy $c = 120\frac{J}{K \cdot kg}$

Melting point of the alloy $T = 330^{\circ}C$

Latent heat of the alloy $L = \frac{24{,}000J}{kg}$

Solution: To totally melt the bullet, we need to increase its temperature to the melting point and then change the phase to liquid, as follows:

$$Q = mc\Delta T + mL = 0.01 \times 120 \times (330 - 20) + 0.01 \times 24{,}000 = 612J$$

That energy comes from the kinetic energy, so: $612 = \frac{1}{2}mv^2 \rightarrow v = \sqrt{\frac{2 \times 612}{0.01}} =$ **350 m/s**

Problem 1a.- How fast would a silver bullet had to go to melt on impact assuming all the kinetic energy goes to the bullet?
Consider the initial temperature T=20ºC
Melting point of silver = 961 ºC
Latent heat of fusion of silver=88J/g, specific heat of silver=0.23J/gram ºC

Solution: Like the previous problem, suppose you have 1kg of silver. You need to heat the silver to the melting point first:

$$Q_1 = cm\Delta T = 0.23\frac{J}{g^{\circ}C} \times 1000g \times (961 - 20) = 216{,}000J$$

And then you need to melt it:

$$Q_2 = Lm = 88\frac{J}{g} \times 1000g = 88{,}000J$$

So the total will be **304,000 J**

This energy was originally kinetic energy, so:

$$Q = \frac{1}{2}mv^2 \rightarrow v = \sqrt{\frac{2Q}{m}} = \sqrt{2 \times 304{,}000} =$$ **779 m/s**

Problem 2.- Is it possible to boil water at room temperature (27ºC)? Explain.

Solution: **It is possible** to boil water at room temperature (27ºC), by reducing the external pressure to the vapor pressure that corresponds to 27ºC.

Problem 3.- You add a cube of ice (mass 8 grams) at T=0ºC to a 300-gram drink at T=18ºC (consider the drink to be mainly water).
Calculate the final temperature of the mixture assuming no heat is transferred to the surroundings.
Latent heat of fusion of ice 80cal/g
Specific heat of water 1cal/gram ºC

Solution: The heat necessary to change the phase of the ice is:

$$Q_1 = Lm = 80\frac{cal}{g}\times 8g = 640cal$$

Then the ice will be heated to reach its final temperature *T*, so:

$$Q_2 = cm\Delta T = 1\frac{cal}{g^{\circ}C}\times 8g\times(T-0) = 8Tcal$$

On the other hand the drink will cool down from 18ºC to a final temperature *T*, releasing this amount of heat:

$$Q_3 = cm\Delta T = 1\frac{cal}{g^{\circ}C}\times 300g\times(18-T) = 300(18-T)cal$$

Now, the amount of heat lost by the drink will be gained by the ice, so:

$$300(18-T) = 640+8T \rightarrow 5400-300T = 640+8T \rightarrow T = \frac{5400-640}{300+8} = \mathbf{15.5\ ^{\circ}C}$$

Problem 3a.- How much ice at T=0 ºC do you need to add to a 300-gram drink at T=18ºC (consider the drink to be mainly water) to cool it down to T=0 ºC?
Assume no heat is transferred to the surroundings.
Latent heat of fusion of ice 80cal/g
Specific heat of water 1cal/g ºC

Solution: The ice will change phase absorbing 80m calories and that has to match the heat lost by the drink, so:

$$80m = 300\times\frac{1cal}{g^{\circ}C}\times 18^{\circ}C \rightarrow m = \frac{300\times 18}{80} = \mathbf{67.5\ g}$$