HW 13 Help

30. ORGANIZE AND PLAN In a perfectly insulated container there is no heat flow, so all the work was converted to internal energy according to the first law of thermodynamics. To calculate the internal energy change we need the specific heat of water from Table 13.1.
Known: $m = 1.0\ \text{kg};\ \Delta T = 7°\text{C};\ c = 4186\ \text{J}/(\text{kg}\cdot\text{K})$.
SOLVE The internal energy change is given by Equation 13.2:

$$\Delta U = mc\Delta T = (1.0\ \text{kg})(4186\ \text{J}/(\text{kg}\cdot\text{K}))(7°\text{C}) = 29\ \text{kJ}$$

The amount of work done on the water is given by the first law of thermodynamics:

$$W = \Delta U - Q = (29\ \text{kJ}) - (0) = 29\ \text{kJ}$$

REFLECT There is no heat flow into or out of a perfectly insulated container, so $Q = 0$.

33. ORGANIZE AND PLAN The internal energy equals the thermal energy of the atoms in the gas. We can use the ideal gas law to calculate a new temperature when the pressure and volume double, and use the new temperature to calculate the new internal energy.
Known: $n = 2.0\ \text{mol};\ T = 273\ \text{K};\ p = 1\ \text{atm}$.
SOLVE The internal energy equals the thermal energy:

$$U = \tfrac{3}{2}nRT = \tfrac{3}{2}(2.0\ \text{mol})(8.31\ \text{J}/(\text{mol}\cdot\text{K}))(273\ \text{K}) = 6.8\ \text{kJ}$$

From the ideal gas law $PV = nRT$ we see that the temperature quadruples when both pressure and volume double. Consequently, the internal energy must quadruple as well, to $U_{\text{new}} = 4U = 4(6.8\ \text{kJ}) = 27\ \text{kJ}$. The change in internal energy is:

$$\Delta U = U_{\text{new}} - U = (27\ \text{kJ}) - (6.8\ \text{kJ}) = 20\ \text{kJ}$$

44. ORGANIZE AND PLAN In an adiabatic process there is no heat flow, so the required work equals the change in internal energy. Oxygen and nitrogen are both diatomic gases.

Known: $n = 1\text{ mol}$; $\Delta T = 1°\text{C}$.

SOLVE The required work equals the change in internal energy.

$$W = \Delta U = \tfrac{5}{2} nR\Delta T = \tfrac{5}{2}(1\text{ mol})\big(8.31\text{ J/}(\text{mol}\cdot\text{K})\big)(1°\text{C}) = 2\times 10^1\text{ J}$$

REFLECT The relative amounts of nitrogen and oxygen did not matter, only the fact that we considered air to be a diatomic gas. This is almost, but no entirely, true. Air also contains 1% argon, which is a noble (monatomic) gas, and smaller amounts of other gases.

54. ORGANIZE AND PLAN The heat lost is the change in internal energy minus the work done. The number of required repetitions is the total calories "burned" divided by the energy expended per repetition.

Known: $m = 125\text{ kg}$; $\Delta y = 42\text{ cm}$; $\Delta U = 1.3\text{ kJ}$; $\Delta U_{\text{total}} = 100\text{ kcal}$.

SOLVE (a) The work to lift the weight once is force times displacement:

$$W = F\Delta y = mg\Delta y = (125\text{ kg})(9.80\text{ m/s}^2)(42\text{ cm}) = 0.51\text{ kJ}$$

The heat lost is:

$$Q = \Delta U - W = (1.3\text{ kJ}) - (0.51\text{ kJ}) = 0.79\text{ kJ}$$

(b) The number of repetitions necessary to burn 100 kcal is:

$$\frac{\Delta U_{\text{total}}}{\Delta U} = \frac{(100\text{ kcal})}{(1.3\text{ kJ})} = 3.2\times 10^2$$

REFLECT 320 repetitions would be impossible for most people when lifting 125 kg.

56. ORGANIZE AND PLAN The entropy change is the heat removed from the steam divided by the temperature. The heat removed can be calculated using the heat of vaporization from Table 13.3.

Known: $m = 75$ g; $T = 100°\text{C}$; L_v=2.26×10^6 J/kg.

SOLVE The heat removed from the steam to condense it is:

$$Q = -mL_v = -(75\text{ g})(2.26\times10^6\text{ J/kg}) = -1.7\times10^5\text{ J}$$

The entropy change is:

$$\Delta S = \frac{Q}{T} = \frac{(-1.7\times10^5\text{ J})}{(100°\text{C})} = \frac{(-1.7\times10^5\text{ J})}{(373\text{ K})} = -4.5\times10^2\text{ J/K}$$

REFLECT The entropy change for the steam is negative when heat is removed.

63. ORGANIZE AND PLAN The efficiency is the ratio between work done and heat used.

Known: $W = 650$ J; $Q_H = 1270$ J.

SOLVE The heat engine's efficiency is:

$$e = \frac{W}{Q_H} = \frac{(650\text{ J})}{(1270\text{ J})} = 0.512.$$

REFLECT In most applications 51.2% would be a very good efficiency.

68. ORGANIZE AND PLAN In a Carnot cycle, the efficiency is one minus the temperature ratio between the cold and hot reservoirs.

Known: $T_C = 20°\text{C}$; $e_{\text{Carnot}} = 0.5$.

SOLVE The Carnot efficiency is:

$$e_{\text{Carnot}} = 1 - \frac{T_C}{T_H}$$

which we can rewrite for to calculate the maximum temperature:

$$T_H = \frac{1}{1-e_{\text{Carnot}}}T_C = \frac{1}{1-0.5}20°\text{C} = 6\times10^2\text{ K}$$

REFLECT When the Carnot efficiency is 0.5, the hot reservoir is twice the temperature of the cold reservoir.

72. ORGANIZE AND PLAN The coefficient of performance of a refrigerator (to which we count air-conditioning systems) is the heat removed divided by the required work.

Known: $\text{COP} = 3.2;\ P = 1200\ \text{W};\ t = 24\ \text{h}.$

SOLVE The electrical energy (required work) consumed in 24 h is:

$$W = Pt = (1200\ \text{W})(24\ \text{h}) = 1.0\times10^{8}\ \text{J}$$

The amount of heat removed from the house is:

$$Q_C = \text{COP}\times W = (3.2)(1.0\times10^{8}\ \text{J}) = 3.3\times10^{8}\ \text{J}$$

REFLECT The higher the COP, the larger the amount of heat removed.

84. ORGANIZE AND PLAN We will use the formula for work done on a gas in an isothermal process twice: first for the two-fold compression, then for the ten-fold compression. We will use subscript 1 for the first case, subscript 2 for the second case. By combining the resulting two equations we can calculate the work in the second case.

Known: $W_1 = 600\ \text{J};\ V_{f,1} = V_i/2;\ V_{f,2} = V_i/10.$

SOLVE The work done on a gas in an isothermal process is:

$$W = nRT\ln\left(\frac{V_i}{V_f}\right)$$

Write down this equation for case 1 and case 2 and divide the resulting two equations with each other:

$$\frac{W_2}{W_1} = \frac{nRT\ln\left(\frac{V_i}{V_{f,2}}\right)}{nRT\ln\left(\frac{V_i}{V_{f,1}}\right)} = \frac{\ln\left(\frac{V_i}{V_{f,2}}\right)}{\ln\left(\frac{V_i}{V_{f,1}}\right)}$$

Solve this for the work done in the second case:

$$W_2 = W_1\frac{\ln\left(\frac{V_i}{V_{f,2}}\right)}{\ln\left(\frac{V_i}{V_{f,1}}\right)} = (600\ \text{J})\frac{\ln(10)}{\ln(2)} = 2.0\ \text{kJ}$$

REFLECT The technique demonstrated here, dividing an equation with values from one case with the same equation with values from another case, is often useful to determine how fractional changes in one quantity vary with fractional changes in another quantity.

90. ORGANIZE AND PLAN Because we can assume a constant temperature, we know from the ideal gas law that the product of pressure and volume is constant. The work can be calculated from the formula for an isothermal process.

Known: $P_D = 80$ mm Hg; $P_S = 125$ mm Hg; $d_D = 1.52$ mm; $T = 37°$C.

SOLVE (a) The product of pressure and volume is constant:

$$P_D V_D = P_S V_S$$

Express the spherical volumes in terms of diameters and solve for the diameter at maximum pressure:

$$P_D \tfrac{\pi}{6} d_D^{\,3} = P_S \tfrac{\pi}{6} d_S^{\,3}$$

$$d_S = \sqrt[3]{\frac{P_D}{P_S}} d_D = \sqrt[3]{\frac{(80 \text{ mm Hg})}{(125 \text{ mm Hg})}}(1.52 \text{ mm}) = 1.3 \text{ mm}$$

(b) The work done is calculated from the expression for work done in an isothermal process, and using the ideal gas law to substitute nRT for PV:

$$W = nRT \ln\left(\frac{V_D}{V_S}\right) = P_S V_S \ln\left(\frac{d_D^{\,3}}{d_S^{\,3}}\right) = \tfrac{\pi}{2} P_S d_S^{\,3} \ln\left(\frac{d_D}{d_S}\right) = \tfrac{\pi}{2}(125 \text{ mm Hg})(1.3 \text{ mm})^3 \ln\left(\frac{(1.52 \text{ mm})}{(1.3 \text{ mm})}\right) = 8.8\ \mu\text{J}$$

REFLECT This is the work done per heart beat. If you assume a certain number of beats per minute, you can calculate the work done over a time period.
Note that we did not need to know the temperature of the gas bubble, only that the temperature was constant.