___ 1 A lake with 6.50×10^9 kg of water, which has a specific heat of 4180 J/(kg °C), warms from 5 °C to 16 °C. The amount of heat transferred to the lake is

A) 2.99×10^{15} J B) 2.99×10^{14} J C) 1.49×10^{14} J D) 4.48×10^{14} J E) 2.66×10^{14} J

Solution:

The heat transferred to the lake is $mc\Delta T = 6.50 \times 10^9 \times 4180 \times (16 - 5)$ J $= 2.99 \times 10^{14}$ J.

The correct answer is: B

___ 2 A 3 kg mass of metal of specific heat 0.1 kcal/ kg °C at a temperature of 600 °C is dropped into 1 kg water at 30 °C. With no heat losses to the surroundings and at atmospheric pressure determine the equilibrium temperature of the mixture, and if it is 100 °C, calculate what mass of water is turned into steam at this temperature.

The specific heat of water is 1 kcal/(kg °C) and its heat of vaporization is 540 kcal/ kg.

A) 100 °C and 74 g of steam B) 100 °C and 15 g of steam
C) 100 °C and 296 g of steam D) The equilibrium temperature is not 100 °C.
E) 100 °C and 148 g of steam

Solution:

Heating the water to 100 °C takes $1 \times 1.00 \times (100 - 30)$ kcal = 70.0 kcal.

Cooling the metal to 100 °C releases $3 \times 0.100 \times (600 - 100)$ kcal = 150. kcal.

The excess heat 80.0 kcal evaporate (80.0/540) kg = 148 g water. (If this number is negative, the equilibrium temperature is less than 100 °C. If the mass of water evaporated exceeds the mass of water available, the equilibrium temperature exceeds 100 °C.)

The correct answer is: E

___ 3 Besides Joule's classic experiment, another way of demonstrating the equivalence of mechanical energy and heat is the following: Put some lead shot in a glass tube. Seal both ends of the tube. Invert the tube quickly several times, and measure the temperature of the shot. If you assume that all the mechanical energy is transfered as heat into the lead shot, and none of that energy is lost, what is the change in the temperature of the shot if the tube is 1.95 m long. The mass of the shot is 0.150 kg of shot, and the tube is inverted 20.0 times? [The specific heat of lead is 128. J/ kg °C.]

A) 1.49 °C B) 0.448 °C C) 2.99 °C D) 5.98 °C E) 19.9 °C

Solution:

The potential energy of the lead is converted into kinetic energy which is converted into heat. The amount per inversion is mgh where $m = 0.150$ kg, $g = 9.81\,\mathrm{m/s^2}$ and $h = 1.95$ m. During 20.0 inversions the heat in is therefore $20.0\,mgh = 57.4\,\mathrm{kg\,m^2/s^2}$. Heat in $= mc\Delta T$ so $\Delta T = \dfrac{57.4\,\mathrm{kg\,m^2/s^2}}{19.2\,\mathrm{J/(kg\,°C)}} = 2.99$ °C. (Note that $\mathrm{J} = \mathrm{kg\,m^2/s^2}$.)

The correct answer is: C

___ 4 An ideal gas initially at 100°C and pressure $P_1 = 250$ kPa occupies a volume $V_1 = 4.5$ L. It undergoes a quasistatic, isothermal expansion until its pressure is reduced to 150 kPa. How much heat enters the gas during this process? $R = 8.314$ J/(mol K) = 0.08206 L atm/(mol K).

A) 116 J B) 640 J C) 320 J D) 575 J E) 850 J

Solution:

The initial temperature, pressure and volume are (373 K, 250 kPa, and 4.5 L.) The final temperature, pressure and volume are (373 K, 150 kPa, and V_f.)

The heat in is the work done plus the increase in internal energy. The internal energy of an ideal gas depends only on its temperature, so its increase is zero and the heat in is the work done by the gas. That is $\int_{4.5\,\mathrm{L}}^{V_f} P\,dV = \int_{4.5\,\mathrm{L}}^{(250)(4.5)\,\mathrm{L}/150} nRT\frac{dV}{V}$. During the process $nRT = PV$ at any point including the start.

So this is $(250\,\mathrm{kPa})(0.0045\,\mathrm{m}^3)\ln\left[\frac{\frac{(250)(4.5)\,\mathrm{L}}{150}}{4.5\,\mathrm{L}}\right] = 575\,\mathrm{J}$

The correct answer is: D

___ 5 An ideal gas with an initial volume of 4.00 L at a pressure of 4.00 atm is compressed adiabatically until it has a volume of 1.00 L and then cooled at constant volume until its temperature drops to its initial value. The final pressure is

A) 0.75 atm B) 2.40 atm C) 32.0 atm D) 1.33 atm E) 16.0 atm

Solution:

	P	V	T
A	4.00 atm	4.00 L	T_0
B	P_B	1.00 L	T_B
C	P_C	1.00 L	T_0

Call state A: $(P,V,T) = (4.00\,\mathrm{atm}, 4.00\,\mathrm{L}, T_0)$, B: $(P_B, 1.00\,\mathrm{L}, T_B)$ and C: $(P_C, 1.00\,\mathrm{L}, T_0)$. Use the ideal gas law for C and A : $P_C \times 1.00\,\mathrm{L} = nRT_0$, $4.00\,\mathrm{atm} \times 4.00\,\mathrm{L} = nRT_0$. Equate the two: $P_C \times 1.00\,\mathrm{L} = 4.00\,\mathrm{atm} \times 4.00\,\mathrm{L}$. That is $P_C = 16.0\,\mathrm{atm}$.

The nature of the processes that bring the gas to the various states need not be used; it would be needed if T_B or P_B were to be found.

The correct answer is: E

___ 6 A cylinder contains 20 L of air at 1 atm. The ratio of C_P to C_V for air is 1.41. If this sample of air is compressed adiabatically to a volume of 5 L, the pressure after compression is approximately

A) 2.7 atm B) 8.4 atm C) 9.7 atm D) 7.1 atm E) 4.0 atm

Solution:

When an ideal gas undergoes an adiabatic process the product PV^γ stays the same. The initial and final pressures and volumes are related by $P_i V_i^\gamma = P_f V_f^\gamma$, so that $P_f = (V_i/V_f)^\gamma P_i$. This gives $P_f = \left[\frac{20\,\mathrm{L}}{5\,\mathrm{L}}\right]^\gamma 1\,\mathrm{atm} = 4^{1.41}\,\mathrm{atm} = 7.1\,\mathrm{atm}$

The correct answer is: D

1. B
2. E
3. C
4. D
5. E
6. D