UNIVERSITY OF OTTAWA
Principles of Physics
PHY1321/1331 FALL 2016
Dr. A. Czajkowski

Assignment 5: ENTROPY and KINEMATICS 1-D Motion
Assigned: Oct 14 *Due: Oct 21 6:00PM*

STUDENT #: ________________
NAME: ______________________

1 A 1.00-mol sample of a diatomic ideal gas, initially having pressure P and volume V, expands so as to have pressure $2P$ and volume $2V$. Determine the entropy change of the gas in the process.

$$\Delta S = nC_V \ln\left(\frac{T_f}{T_i}\right) + nR\ln\left(\frac{V_f}{V_i}\right) \quad = (1.00 \text{ mol})\left[\frac{5}{2}(8.314 \text{ J/mol}\cdot\text{K})\right]\ln\left(\frac{2P\cdot 2V}{PV}\right) + (1.00 \text{ mol})(8.314 \text{ J/mol}\cdot\text{K})\ln\left(\frac{2V}{V}\right)$$

$$\Delta S = \boxed{34.6 \text{ J/K}}$$

7 A 1 500-kg car is moving at 20.0 m/s. The driver brakes to a stop. The brakes cool off to the temperature of the surrounding air, which is nearly constant at 20.0°C. What is the total entropy change?

The car ends up in the same thermodynamic state as it started, so it undergoes zero changes in entropy. The original kinetic energy of the car is transferred by heat to the surrounding air, adding to the internal energy of the air. Its change in entropy is

$$\Delta S = \frac{\frac{1}{2}mv^2}{T} = \frac{750(20.0)^2}{293} \text{ J/K} = \boxed{1.02 \text{ kJ/K}}.$$

3. What change in entropy occurs when a 27.9-g ice cube at –12°C is transformed into steam at 115°C?

We assume a constant specific heat for each phase. As the ice is warmed from –12°C to 0°C, its entropy increases by

$$\Delta S = \int_i^f \frac{dQ}{T} = \int_{261\text{ K}}^{273\text{ K}} \frac{mc_{\text{ice}}dT}{T} = mc_{\text{ice}}\int_{261\text{ K}}^{273\text{ K}} T^{-1}dT = mc_{\text{ice}}\ln T\Big|_{261\text{ K}}^{273\text{ K}}$$

$$\Delta S = 0.027\,0 \text{ kg}(2\,090 \text{ J/kg}\cdot{}^\circ\text{C})(\ln 273 \text{ K} - \ln 261 \text{ K}) = 0.027\,0 \text{ kg}(2\,090 \text{ J/kg}\cdot{}^\circ\text{C})\left(\ln\left(\frac{273}{261}\right)\right)$$

$$\Delta S = 2.54 \text{ J/K}$$

As the ice melts its entropy change is $\Delta S = \frac{Q}{T} = \frac{mL_f}{T} = \frac{0.027\,0 \text{ kg}(3.33\times 10^5 \text{ J/kg})}{273 \text{ K}} = 32.9 \text{ J/K}$

As liquid water warms from 273 K to 373 K,

$$\Delta S = \int_i^f \frac{mc_{\text{liquid}}dT}{T} = mc_{\text{liquid}}\ln\left(\frac{T_f}{T_i}\right) = 0.027\,0 \text{ kg}(4\,186 \text{ J/kg}\cdot{}^\circ\text{C})\ln\left(\frac{373}{273}\right) = 35.3 \text{ J/K}$$

As the water boils and the steam warms,

$$\Delta S = \frac{mL_v}{T} + mc_{\text{steam}}\ln\left(\frac{T_f}{T_i}\right)$$

$$\Delta S = \frac{0.027\,0 \text{ kg}(2.26\times 10^6 \text{ J/kg})}{373 \text{ K}} + 0.027\,0 \text{ kg}(2\,010 \text{ J/kg}\cdot{}^\circ\text{C})\ln\left(\frac{388}{373}\right) = 164 \text{ J/K} + 2.14 \text{ J/K}$$

The total entropy change is $(2.54 + 32.9 + 35.3 + 164 + 2.14) \text{ J/K} = \boxed{236 \text{ J/K}}$.

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4 A 1.00-kg iron horseshoe is taken from a forge at 900°C and dropped into 4.00 kg of water at 10.0°C. Assuming that no energy is lost by heat to the surroundings, determine the total entropy change of the horseshoe-plus-water system

$c_{\text{iron}} = 448\ \text{J/kg}\cdot{}^\circ\text{C}$; $c_{\text{water}} = 4\,186\ \text{J/kg}\cdot{}^\circ\text{C}$ since $Q_{\text{cold}} = -Q_{\text{hot}}$:

we have $4.00\ \text{kg}(4\,186\ \text{J/kg}\cdot{}^\circ\text{C})(T_f - 10.0^\circ\text{C}) = -(1.00\ \text{kg})(448\ \text{J/kg}\cdot{}^\circ\text{C})(T_f - 900^\circ\text{C})$

which yields $T_f = 33.2^\circ\text{C} = 306.2\ \text{K}$

$$\Delta S = \int_{283\ \text{K}}^{306.2\ \text{K}} \frac{c_{\text{water}} m_{\text{water}} dT}{T} + \int_{1173\ \text{K}}^{306.2\ \text{K}} \frac{c_{\text{iron}} m_{\text{iron}} dT}{T}$$

$$\Delta S = c_{\text{water}} m_{\text{water}} \ln\left(\frac{306.2}{283}\right) + c_{\text{iron}} m_{\text{iron}} \ln\left(\frac{306.2}{1\,173}\right)$$

$$\Delta S = (4\,186\ \text{J/kg}\cdot\text{K})(4.00\ \text{kg})(0.078\,8) + (448\ \text{J/kg}\cdot\text{K})(1.00\ \text{kg})(-1.34)$$

$$\Delta S = \boxed{718\ \text{J/K}}$$

5 Using the general definition of entropy find the expression for entropy change in calorimetric process in which the two

$$\Delta S = \int_i^f \frac{dQ}{T} = \int_{T_1}^{T_f} \frac{dQ_1}{T} + \int_{T_2}^{T_f} \frac{dQ_2}{T} = \int_{T_1}^{T_f} \frac{m_1 c_1 dT}{T} + \int_{T_2}^{T_f} \frac{m_2 c_2 dT}{T} = m_1 c_1 \ln\frac{T_f}{T_1} + m_2 c_2 \ln\frac{T_f}{T_2}$$

different substances exchange heat until the equilibrium is established (there is not phase change for any of the substance within the range of temperatures in question)