

1. A hiker caught in a rainstorm absorbs 1 liter of water in his/her clothing. It is windy so that this volume is quickly evaporated at 20°C (the heat of vaporization of water is 2447 kJ/kg at this temperature).

- a. If the hiker is the “system” calculate q , the heat transferred. (3 points)

$$\text{Solution: } q = -m \Delta H_{\text{vap}} = -\rho V \Delta H_{\text{vap}} = -(1 \text{ kg/L})(1 \text{ L})(2447 \text{ kJ/kg}) = -2447 \text{ J}$$

is the heat lost by the hiker.

$$q = \underline{\hspace{10em}}.$$

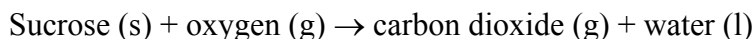
- b. If all this heat were removed from the hiker what drop in body temperature would the hiker experience (ignore the metabolism of the hiker)? The hiker weighs 60 kg and has a heat capacity equal to that of water. (3 points)

$$\text{Solution: } mC_p \Delta T = -\Delta H_{\text{vap}}$$

$$\Delta T = -\Delta H_{\text{vap}}/mC_p = -2447 \text{ kJ}/60 \text{ kg}/4.18 \text{ kJ/kg-K} = -9.75 \text{ K}$$

$$\text{Decrease in body temperature} = \underline{\hspace{10em}}.$$

- c. How many grams of sucrose would the hiker have to metabolize (quickly) to replace the heat of evaporating one liter of water to maintain his/her original body temperature? You can use the heat of reaction at 25°C; the reaction is:



(4 points)

Solution:



$$\begin{aligned} \Delta H_{\text{rxn}} &= 12 \Delta H_f^\circ (\text{CO}_2) + 11 \Delta H_f^\circ (\text{H}_2\text{O}) - \Delta H_f^\circ (\text{C}_{12}\text{H}_{22}\text{O}_{11}) - 12 \Delta H_f^\circ (\text{O}_2) \\ &= 12(-393.5) + 11(-285.8) - (-2222) \text{ kJ/mol} = -5.64 \text{ MJ/mol} \end{aligned}$$

We need the molar mass of sucrose $M = 342 \text{ g/mol}$.

$$\begin{aligned} \text{grams of sucrose} &= -q/\Delta H_{\text{rxn}}M \\ &= -2.447 \times 10^6 \text{ J}/5.64 \times 10^6 \text{ J/mol}(342 \text{ g/mol}) = 148 \text{ grams} \end{aligned}$$

$$\text{Grams of sucrose needed to maintain temperature} = \underline{\hspace{10em}}.$$

2. a. An engineer is designing a solar heating unit for a house. A bed of granite rocks with a surface area of 10 m^2 and volume 1 m^3 will be heated by direct sunlight. The specific heat of the rocks is $4 \text{ Jg}^{-1}\text{K}^{-1}$ and the average density is 4000 kg/m^3 . Assume that the effective radiant power of the sun is 1000 W/m^2 and that there are four hours of effective heating per day. Assuming a morning temperature of 298 K , perfect heat transfer, and no losses, what final temperature will be achieved by the rocks at the end of the day? (3 points)

Solution: $mC_p \Delta T = q_{\text{absorbed}}$. Solving for temperature change, we have

$$\Delta T = q_{\text{absorbed}}/mC_p = 1.44 \times 10^8 \text{ J}/(4 \times 10^6 \text{ g})(4 \text{ Jg}^{-1}\text{K}^{-1}) = 9 \text{ K}$$

The mass of rocks is $4000 \text{ kg/m}^3 (1 \text{ m}^3) = 4000 \text{ kg}$

$$\text{The heat absorbed is } (1000 \text{ W/m}^2)(14400 \text{ sec})(10 \text{ m}^2) = 1.44 \times 10^8 \text{ J}$$

Final temperature = _____.

- b. Assuming perfect heat exchange between the rocks and pumped air, what volume of air ($C_p = 29.0 \text{ Jmol}^{-1}\text{K}^{-1}$) can be heated by 10 K ? Assume that the starting temperature is 280 K and the pressure is 1 atm (2 points)

Solution: $q_{\text{rock}} = -q_{\text{air}}$

$$mC_{p,\text{rock}}\Delta T_{\text{rock}} = n_{\text{air}}C_{p,\text{air}}\Delta T_{\text{air}} = (P_{\text{air}}V_{\text{air}}/RT_{\text{air}})C_{p,\text{air}}\Delta T_{\text{air}}$$

$$V_{\text{air}} = (RT_{\text{air}}/P_{\text{air}}) mC_{p,\text{rock}}\Delta T_{\text{rock}}/C_{p,\text{air}}\Delta T_{\text{air}}$$

$$= (0.08206 \text{ L-atm/mol-K})(280 \text{ K})/(1 \text{ atm}) (4 \times 10^6 \text{ g})(4 \text{ Jg}^{-1}\text{K}^{-1})(9 \text{ K})/(29 \text{ J/mol-K})(10 \text{ K})$$

$$V_{\text{air}} = 1.1 \times 10^7 \text{ L}$$

Volume of air that can be heated = _____.

3. a. How much solar energy is required to heat 1 mole of circulation water from 300 to 310 K ? (2 points)

$$q = \Delta H = C_p \Delta T = (75.29 \text{ J/mol-K})(10 \text{ K}) = 753 \text{ J}$$

Energy required = _____.

- b. A flow of air at 275 K enters a heat exchanger at 22.5 L/sec . The hot water (310 K) supplied from a flat plate solar panel enters the inner tubing of the heat exchanger at 0.018 L/sec . Assuming that the heat exchanger has no losses and that the water and air reach equilibrium as they exit calculate the temperature of the heated air. (3 points)

$$n_{\text{air}} = PV/RT = (1 \text{ atm})(22.5 \text{ L})/(0.08206 \text{ L-atm/mol-K})(275\text{K}) = 1.0 \text{ mol (per second)}$$

$$n_{\text{water}} = \rho V/M = (1000 \text{ g./L})(0.018 \text{ L})/18 \text{ g/mol} = 1.0 \text{ mol (per second)}$$

$$C_{p,\text{air}}(T_f - T_{\text{air}}) = -C_{p,\text{water}}(T_f - T_{\text{water}})$$

$$T_f = (C_{p,\text{air}}T_{\text{air}} + C_{p,\text{water}}T_{\text{water}})/(C_{p,\text{air}} + C_{p,\text{water}})$$

$$= ((29)(275) + (75.3)(310))/(29 + 75.3) = 300 \text{ K}$$

Temperature of heated air = _____.