

Example Q2 PS 2

1. Calculate the changes in the total entropy of the universe as a consequence of the following:

- A copper block of mass 1 kg, temperature 100 °C and specific heat capacity c equal to $0.4 \text{ J g}^{-1} \text{ K}^{-1}$ is placed in a lake of large thermal capacity at 10 °C.
- An equivalent block at 10 °C is dropped into the lake from a height of 10 m.
- Two such copper blocks, one at 0 °C and one at 100 °C, are joined together.

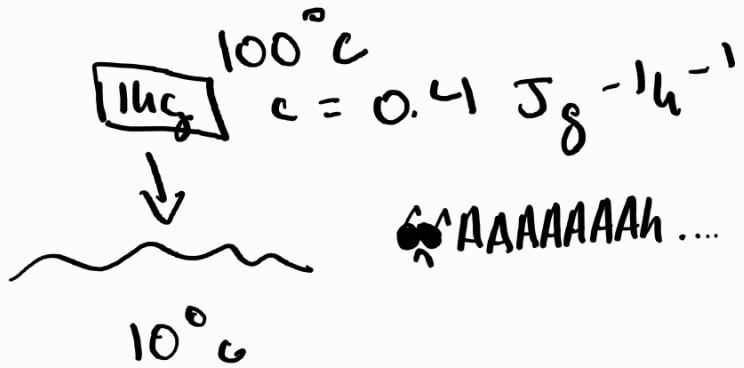
You may assume that c is independent of temperature.

Semester 1, 2022/2023

Part 1

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1. a)

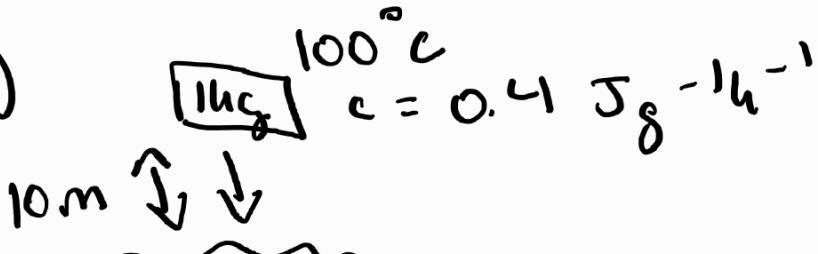


$$H = U + PV$$

$$dH = TdS + Vdp$$

$$dU = TdS - pdV$$

b)



10°C

c)



Coment:

a)

Calculate the changes in the total entropy of the universe as a consequence of the following:

a) A copper block of mass 1 kg, temperature 100°C and specific heat capacity c equal to $0.4 \text{ J g}^{-1} \text{ K}^{-1}$ is placed in a lake of large thermal capacity at 10°C .

$\Delta S = S_f - S_i = \int_i^f \frac{dQ_{rev}}{T}$ for any path, because S is function of state
lake is much bigger, so can be treated as a heat reservoir
entropy change has two components

$\Delta S_{Cu} = \int_{T_i}^{T_f} \frac{CdT}{T} = C \ln \frac{T_f}{T_i}$ negative, because heat release
heat released by Cu (CdT) is heat gained by lake, but lake temperature is unaffected

$$\Delta S_{lake} = -\frac{1}{T_f} \int_{T_i}^{T_f} CdT = C \frac{T_i - T_f}{T_f}$$

$$C = C_m$$

b)

Calculate the changes in the total entropy of the universe as a consequence of the following:

b) An equivalent block at 10°C is dropped into the lake from a height of 10 m.

height or 10 m
no heat flow, but lake gains energy equivalent to initial gravitational potential energy of block

$$\Delta S = \frac{mgh}{T_f} = \frac{1 \text{ kg} \cdot 9.81 \frac{\text{kg m}}{\text{s}} \cdot 10 \text{ m}}{283 \text{ K}} = 0.35 \text{ J/K}$$

Remember $dW = -Fdx = -dQ$

c)

Calculate the changes in the total entropy of the universe as a consequence of the following:
c) Two such copper blocks, one at 0 °C and one at 100 °C, are joined together. You may assume that C is independent of temperature.

$$T_a = 0 \text{ }^{\circ}\text{C} = 273 \text{ K}, \quad T_b = 100 \text{ }^{\circ}\text{C} = 373 \text{ K}$$

$$C(T_f - T_a) = -C(T_f - T_b)$$

$$T_f = \frac{T_a + T_b}{2} = 323 \text{ K}$$

$$\Delta S = \int_{T_a}^{T_f} \frac{CdT}{T} + \int_{T_b}^{T_f} \frac{CdT}{T} = C \left(\ln \frac{T_f}{T_a} + \ln \frac{T_f}{T_b} \right) = cm \ln \frac{T_f^2}{T_a \cdot T_b} = 9.702 \text{ J/K}$$