PHYS 334 Exam #2

Name:_____Solution_____ 04/06/2022

Choose the right answer or fill in the blank.

1. [20 pts]
   a) A Carnot engine can convert 100% heat into useful work. [True, **False**]
   b) A Joule-Thomson Process is where the coolant is cooled below the temperature of ----------.

      [[Environment, Hot reservoir, **Cold reservoir**]

      ]
   c) The Joule-Thomson Process does not work for ----------.

      [Liquid, High density gas, **Ideal gas**]
   d) Total energy needed to create a system from nothing and put it into the environment is called ----------.

      [**Enthalpy**, Helmholtz free energy, Gibbs free energy]
   e) If a system is in a good thermal contact with the environment, but is in mechanical and diffusion isolation, its ---------- free energy is minimum.

      [**Helmholtz**, Gibbs, Grand]
   f) If a system is in a good thermal and mechanical contacts with the environment, but is in diffusion isolation, its ---------- free energy is minimum.

      [Helmholtz, **Gibbs**, Grand]
   g) If a system is in a good thermal and diffusion contacts with the environment, but is in mechanical isolation, its ---------- free energy is minimum.

      [Helmholtz, Gibbs, **Grand**]
   h) The slope of the phase boundary between ice and water is ----------.

      [Positive, **negative**, zero]
   i) You can ---------- the melting point of ice by lowering the pressure.

      [lower, **raise**, not change]
   j) If pressure and temperature are below the ----------, you can get gas from solid phase of the substance directly.

      [critical point, Standard values, **triple point**]

Data for water: Latent Heat of fusion = 333 J/g Latent heat of evaporation = 2400 J/g Heat Capacity =4.186 J/g/K

Explain your answer and show your work for full credit.

2. A power plant produces 1.5 GW of electricity at an efficiency of 35%.
   a) [5 Pts] Find the rate of expelled waste heat.
   Similar to Problem 4.3
   Since $e = W/Q_h = W/(Q_c + W) \Rightarrow Q_c + W = W/e \Rightarrow Q_c = W(1/e - 1)$
   As $Q_c + W = Q_h$
   where Q_c is the heat expelled to cold reservoir, that is waste heat.
   $\Rightarrow Q_c = 1.5\ GW*(1/.35-1) = 2.786\ GW$

   b) [5 Pts] Suppose that all waste energy is dumped into river and river water is evaporated. Find the rate of water evaporation.
   Since $Q = mL \Rightarrow m = Q/L = 2.786\times10^9\ J/s / 2400\times10^3\ J/kg = 1.16\times10^3\ kg/s$

3. The ground state of Hydrogen atom has energy -13.6 eV and the 2nd excited state has energy of -1.5 eV. The ground state has only one while 2nd excited state has actually 9 independent states. The Hydrogen atom is kept at room temperature (suppose room temperature is 27°C). Find

   a) [5 pts] The entropy of the Hydrogen atom in its ground state.
   $S = k\ln(\Omega)$, Ground State $\Rightarrow \Omega = 1$ (since only one independent state).

   Therefore $S = 0$

   b) [5 Pts] The Helmholtz free energy of the Hydrogen atom in its ground sate.
   $F = U - TS = -13.6\ eV$

   c) [5 Pts] The entropy of the Hydrogen atom in 2nd excited sate.
   $S = k\ln(9) = 8.62\times10^{-5}\ eV/K * 2.197 = 1.89\times10^{-4}\ eV/K = 2.7+10\text{-}23\ J/K$

   d) [5 Pts] The change in Helmholtz free energy of the Hydrogen atom if it moves to its 2nd excited sate.
   $\Delta F = \Delta U - T\Delta S = (12.1 - 300*1.89\times10^{-4}) = 12.04\ eV$

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