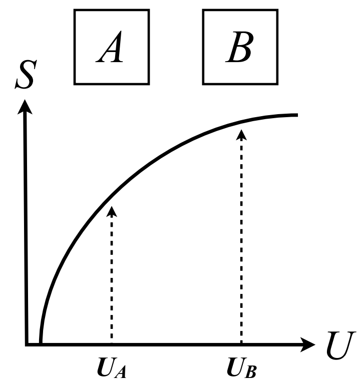
Sample

Physics 3410 Exam 2 Solutions

1. This graph shows the entropy of a system as a function of its energy. There are two copies of the system next to each other, one with energy U_A and one with energy U_B.

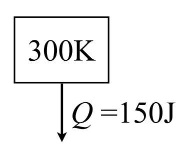


$\boxed{3}$ (a) **B** If the systems are put into contact, heat will flow
A) from A to B (A is "hotter")
B) from B to A (B is "hotter")

$\boxed{3}$ (b) **C** These systems have
A) negative temperature
B) negative heat capacity
C) neither of these

$\boxed{3}$ 2. **B** A system absorbs 50 J of heat, and its temperature drops by 1 K. This system has
A) negative temperature **B)** negative heat capacity **C)** neither of these

$\boxed{3}$ 3. 150 J of heat flows out of a thermal reservoir at temperature $T = 300\,\text{K}$. Find the change ΔS in the reservoir's entropy.

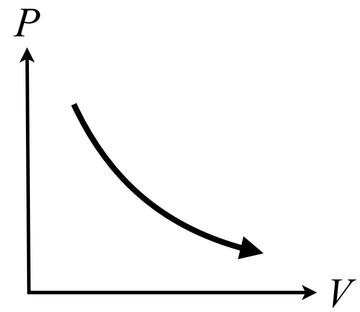


$$\Delta S = \frac{Q}{T} = \frac{-150\,\text{J}}{300\,\text{K}} = \boxed{-0.5\,\text{J/K}}$$

$\boxed{2}$ 4. By what process can a system decrease in entropy? (And I don't mean "by increasing the entropy somewhere else").

By releasing heat

5. Consider this process of an ideal gas on a PV diagram.



$\boxed{3}$ (a) **C** This process is
A) constant-volume **B)** isobaric **C)** isothermal

$\boxed{3}$ (b) **B** During this process,
A) work flows into the system
B) work flows out of the system
C) no work is involved

$\boxed{3}$ (c) **A** During this process,
A) heat flows into the system
B) heat flows out of the system
C) no heat is involved

6. Answer the following true/false questions about an adiabatic process. Feel free to explain your answer.

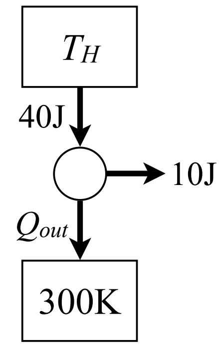
$\boxed{1}$ (a) **F** An adiabatic process is never quasistatic.

$\boxed{1}$ (b) **T** An adiabatic process does not change a system's entropy.

$\boxed{1}$ (c) **T** During an adiabatic process, no heat flows into or out of the system.

$\boxed{1}$ (d) **F** An adiabatic process is relatively slow.

7. This figure shows a heat engine operating between two reservoirs.



$\boxed{3}$ (a) What is its efficiency?

$$\eta = \frac{W}{Q_{in}} = \frac{10\,\text{J}}{40\,\text{J}} = \boxed{25\%}$$

$\boxed{3}$ (b) How much heat Q_{out} flows into the cold reservoir?

Of the $40\,\text{J}$ that flows in, $10\,\text{J}$ goes out as work, and so $\boxed{30\,\text{J}}$ of energy must leave.

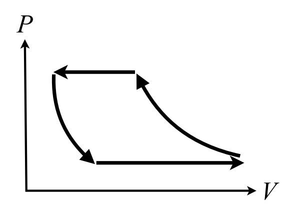
$\boxed{2}$ (c) If this is a Carnot engine, what is the temperature T_H of the hot reservoir?

For a Carnot engine,

$$\eta = 1 - \frac{T_C}{T_H} \implies 0.25 = 1 - \frac{300\,\text{K}}{T_H} \implies T_H = \frac{300\,\text{K}}{0.75} = \boxed{400\,\text{K}}$$

$\boxed{3}$ 8. __B__ This figure shows a cyclic process on a PV diagram. The net work of flow during this cycle is

A) outward **B)** inward **C)** zero



$\boxed{3}$ 9. __C__ When a liter of a certain fuel burns, its internal energy decreases by 80 J ($\Delta U = -80\,\text{J}$) and its Helmholtz free energy F decreases by 50 J ($\Delta F = -50\,\text{J}$). How much work could be done on the environment by burning this liter of fuel?

A) 0 J **B)** 30 J **C)** 50 J **D)** 80 J

The free energy is the amount of energy that can be used as work.

$\boxed{3}$ 10. A system at standard temperature and pressure (300 K, 10^5 Pa) expands from $2\,\text{m}^3$ to $2.1\,\text{m}^3$. What is the change in the Helmholtz free energy ΔF? The temperature and pressure remain constant throughout the expansion.

$dF = -S\,dT - P\,dV + \mu\,dN$, and if T and P are constant,

$$\Delta F = -S\Delta T - P\Delta V = 0 - (10^5\,\text{Pa})(0.1\,\text{m}^3) = \boxed{-10\,\text{kJ}}$$

$\boxed{3}$ 11. C When you burn wood, its enthalpy
A) increases **B)** stays the same **C)** decreases

$\boxed{3}$ 12. I slowly expand a gas in contact with a thermal reservoir. Write the derivative (in the form $\left(\frac{\partial A}{\partial B}\right)_C$) you would use to find the change in the system's entropy.

$$\left(\frac{\partial S}{\partial V}\right)_T$$

13. Consider the new thermodynamic potential $\Phi = F - \mu N$, which has the thermodynamic identity

$$d\Phi = -S\,dT - P\,dV - N\,d\mu$$

$\boxed{3}$ (a) What are the natural variables of Φ? T V μ

$\boxed{3}$ (b) Find $\left(\frac{\partial \Phi}{\partial \mu}\right)_{T,V}$.

If T and V are constant, then

$$d\Phi = -N\,d\mu \implies \left(\frac{\partial \Phi}{\partial \mu}\right)_{T,V} = \boxed{-N}$$

$\boxed{3}$ (c) Find a derivative which is equal to this one, using a Maxwell relation related to Φ.

$$\left(\frac{\partial S}{\partial \mu}\right)_{T,V} =$$

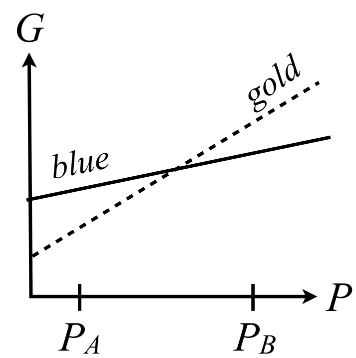
$$\boxed{\left(\frac{\partial N}{\partial T}\right)_{\mu,V}}$$

$\boxed{2}$ 14. **B** At -10° C at standard pressure, ice has a ... Gibbs free energy than liquid water.
A) higher **B)** lower

$\boxed{2}$ 15. When does the Gibbs free energy of ice equal the Gibbs free energy of liquid water?

At the freezing/melting temperature of water

16. This graph shows the Gibbs free energy of two crystal structures (called "blue" and "gold") of toledium, as a function of pressure.



$\boxed{3}$ (a) **B** At which pressure is blue toledium more stable?
A) P_A **B)** P_B

$\boxed{3}$ (b) **B** Which type of toledium is less dense?
A) blue **B)** gold

$dG = V\,dP$, so V is the slope of the line. Gold has a larger slope, and thus a larger volume, and thus a smaller density.

$\boxed{3}$ 17. In the van der Waals model of an ideal gas, $\left(P + a\frac{N^2}{V^2}\right)(V - Nb) = NkT$. Explain what the quantity Nb describes in physical terms.

The total volume of all of the gas molecules.
Or the minimum volume that the gas can occupy.
Or the volume of the gas at $T = 0\,\mathrm{K}$.