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NOTE: TO ENSURE FULL CREDIT EMPHASIZE YOUR ANSWERS AND **INCLUDE DIMENSIONS**. SPECIFY WHICH PRINCIPLES OR LAWS YOU ARE USING. EXPLAIN BRIEFLY WHAT YOU ARE TRYING TO DO. ORGANIZE YOUR WORK LOGICALLY. USE DRAWINGS! Use the correct number of significant figures. **USE scientific notation for numbers larger than 1000 and smaller than 1/1000. Unless otherwise specified, do not use more than 3 significant figures.**

$$k_B = 1.38\cdot 10^{-23}; R = 8.314 J/mole\cdot{}^\circ K = 0.08207 Latm/mole\cdot{}^\circ K; \hbar = \frac{h}{2\pi} = 1.05\cdot 10^{-34} Js;$$

$$\sigma = 5.67\cdot 10^{-8}(Stefan); \dot{Q} = eA\sigma T^4; \Delta U = nC_V\Delta T; C_P - C_V = R; \frac{1}{2}m\overline{\mathrm{v}^2} = \frac{3}{2}k_B T; \dot{Q} = \frac{A\Delta T}{\sum \frac{L_i}{k_i}}$$

$$TV^{\gamma-1} = \text{const}; \text{PV}=Nk_B T = nRT; PV^\gamma = \text{const}; \Delta U = Q + W; \Delta S = \int_i^f \frac{dQ_r}{T}; \lambda = 1/\sqrt{2}\pi d^2 n_V$$

$$ndE = n_0 e^{-\frac{E}{k_B T}} dE; W = -\int_{V_i}^{V_f} PdV; 1cal = 4.186J; L_{water} = 80 cal/g$$

1. Calculate the rms speed of a Helium atom at the temperature of 450ºC. Assume that the molecule has 3 degrees of freedom. (2123m/s)

2. A constant volume gas thermometer is calibrated in dry ice at a temperature of -80.0ºC and 0.900atm for one point and at 78.0ºC with ethyl alohol at 1.635 atm (boiling point).
What Celcius value of absolute zero does the calibration yield? What is the pressure at the freezing and boiling point of water?

$$m = \frac{P_2 - P_1}{T_2 - T_1} = 4.65 \cdot 10^{-3} \frac{atm}{C^\circ}; P_0 = 1.272 atm \qquad P(T) = mT + P_0$$

$$\text{T(P=0)} = -\frac{1.27 atm}{m} = -273.6°\text{C}; \text{ 1.272atm; 1.737 atm}$$

3. Find the density of nitrogen gas at a pressure of 1.00 atm and a temperature of 20.0ºC.
(1.16 kg/m^3 or 1.16g/L)

$$PV = NkT \Rightarrow P = \frac{N}{V}kT = n_V kT = \frac{\rho}{m}kT$$

$$\rho = \frac{Pm}{kT} = \frac{PM}{RT}$$

4. A double pane window of area 1.0 m^2 consists of 2 panes of glass with thickness 4.0 mm, and a space of width 4.0mm filled with Argon. The conductivity constants are: glass 0.80 W/mCº and Argon 0.016 W/m·Cº. Find the rate of heat passing through this window if the inside temperature of a house is 20ºC and the outside is at -10ºC. A=1.00m^2

$$\dot{Q} = \frac{A\Delta T}{\sum \frac{L_i}{k_i}} = \frac{1m^2 \cdot 30C^\circ}{2\frac{0.004}{0.8} + \frac{0.004}{0.016}} = 115W$$

5. A 15.0 gram lead bullet with a velocity of 350 m/s hits a solid brick wall. If all the energy of the bullet is changed into heat, and none of it is transferred to the environment, by what amount will the temperature of lead increase?

c_{lead}=0.030 cal/gCº; c_{iron}=0.107 cal/gCº. The melting point of lead is at 327.3ºC its latent heat of melting is 24.5 J/g =5.85 cal/gCº. How much lead will melt in the process? The original temperature of lead is assumed to be 0 degrees.
(12 grams will melt)

The total K of the bullet is 919J.

It takes Q=mcΔT $=0.030\dfrac{kcal}{kgC^\circ}\cdot 0.015kg\cdot 327.3C^\circ = 0.147kcal = 616J$. to increase the temperature of the bullet from 0 to the melting point, namely 147 cal or 617 Joules. This means that the difference in heat energy (303J) will melt the lead bullet to some degree.

$$303J = mL; m = \frac{303J}{24.5J/g} = 12.4g$$

6 The sun has a surface temperature of 5700 ºK. If its emissivity constant e is equal to 1, calculate its power output. The radius of the sun (a hydrogen gas ball) is 7.0E8 m. The earth's orbital radius around the sun is 1.5E11 meters. Calculate the intensity of the electromagnetic radiation that reaches the surface of the earth's atmosphere.

$$\dot{Q} = eA\sigma T^4 = 1\cdot 4\pi\cdot 49\cdot 10^{16}\cdot 5.67\cdot 10^{-8}\cdot 5700^4 = 3.7\cdot 10^{26}W$$

1.3kW/m^2.

7. The Maxwell speed distribution for a mono-atomic gas is given by $f(\text{v})d\text{v} = 4\pi\left(\dfrac{m}{2\pi k_B T}\right)^{\frac{3}{2}} e^{-\frac{m\text{v}^2}{2k_B T}}\text{v}^2 d\text{v}$.

Find the most probable speed for helium gas at a temperature of 2000 K. Prove the formula you are using. $\dfrac{df}{dv} = 0$

$$\text{v}_{mp} = \sqrt{2}\sqrt{\frac{kT}{m}}$$

8 Assume that the earth's atmosphere has a uniform temperature of 20º C and uniform composition with an effective molar mass of 28.9 g/mol. Show that the pressure depends on height according to $P(y) = P_0 e^{-\frac{mgy}{k_B T}}$

Find the ratio of pressures at a height of 11 km to that at sea-level.

(27.8%)

9 Find the maximum efficiency of a gasoline engine running at a temperature of 350º C. Assume the temperature of the environment to be at 20º C. If 1000 J of heat enters the system. Find the work and heat exhausted. (0.53)

$$0.53 = \frac{W}{Q_h}; W = 0.53 \cdot 1000J = 530J \; ; \; Q_c = 1000 - 530 = 470J$$

10 Calculate the change in entropy of 250g of water, heated slowly from 20 to 80ºC. (Note that dQ=mcdT): 46.6 cal/K

11 Calculate the entropy change of 100 liters of air heated from 20 to 300 degrees C, while its pressure increases from 2 to 10 atmospheres. Find the number of moles involved, the final volume. (Reversible infinitesimal processes.)

$$dS = \frac{dQ}{T} = \frac{1}{T}\left(dU - dW\right) = \frac{1}{T}\left(nC_V dT + PdV\right) = nC_V \frac{dT}{T} + nR\frac{dV}{V}$$

$$\Delta S = nC_V \ln\frac{T_f}{T_i} + nR\ln\frac{V_f}{V_i}$$

$$\text{n=} \frac{2atm \cdot 100L}{0.0821 \cdot 293} = 8.31$$

$$\Delta S = \underbrace{8.31 \cdot R}_{nR}\left(2.5\ln\frac{573}{293} + \ln\frac{39L}{100L}\right) \text{=51J/K}$$