ITECH Euro 1
Thermodynamics 1 - Problems

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A Thermal Properties

1. A piece of copper is dropped into a beaker of water. If the water's temperature increases, what happens to the temperature of the copper? Under what conditions are the water and copper in thermal equilibrium?
2. Rubber has a negative average coefficient of linear expansion. What happens to the size of a piece of rubber as it is warmed?
3. Markings to indicate length are placed on a steel tape in a room that has a temperature of 22 °C. Are measurements made with the tape on a day when the temperature is 27 °C greater than, less than, or the same length as the object's length? Defend your answer.
4. Convert the following to equivalent temperatures on the Celsius and Kelvin scales: (a) the normal human body temperature, 98.6 °F; (b) the air temperature on a cold day, 5.00 °F.
5. The temperature difference between the inside and the outside of an automobile engine is 450 °C. Express this temperature difference on the (a) Fahrenheit scale and (b) Kelvin scale.
6. An aluminum tube is 3 000 m long at 20.0°C. What is its length at (a) 100.0°C and (b) 0.0°C?
7. What mass of steam initially at 130°C is needed to warm 200 g of water in a 100g glass container from 20.0°C to 50.0°C?
8. Liquid helium has a very low boiling point, 4.2 K, and a very low latent heat of vaporization, 2.09×10^4 J/kg. If energy is transferred to a container of boiling liquid helium from an immersed electric heater at a rate of 10.0 W, how long does it take to boil away 1.00 kg of the liquid?
9. The specific heat of water is about two times that of ethyl alcohol. Equal masses

of alcohol and water are contained in separate beakers and are supplied with the same amount of energy. Compare the temperature increases of the two liquids.

10. A small metal crucible is taken from a 200°C oven and immersed in a tub full of water at room temperature (this process is often referred to as quenching). What is the approximate final equilibrium temperature?

11. What is wrong with the statement, "Given any two bodies, the one with the higher temperature contains more heat".

12. Is it possible to convert internal energy into mechanical energy? Explain using examples.

13. The temperature of a silver bar rises by 10.0°C when it absorbs 1.23 kJ of energy by heat. The mass of the bar is 525 g. Determine the specific heat of silver.

14. How much energy is required to change a 40.0 g ice cube from ice at -10.0°C to steam at 110°C?

15. An aluminum cup with a mass of 200 g contains 800 g of water in thermal equilibrium at 80.0°C. The combination of cup and water is cooled uniformly so that the temperature decreases at a rate of 1.50°C/min. At what rate is energy being removed by heat? Express your answer in watts.

16. Steam at 100°C is added to ice at 0°C. (a) Find the amount of ice melted and the final temperature when the mass of steam is 10.0 g and the mass of ice is 50.0 g. (b) Repeat this calculation, taking the mass of steam as 1.00 g and the mass of ice as 50.0 g.

17. A 50.0 g copper calorimeter contains 250 g of water at 20.0°C. How much steam (at 100 °C) must be condensed into the water if the final temperature of the system is to reach 50.0°C?

18. A water heater is operated by solar power. If the solar collector has an area of 6.00 m^2 and the power delivered by sunlight is 550 W/m^2 , how long does it take to increase the temperature of 1.00 m^3 of water from 20.0°C to 60.0°C?

data:
linear expansion coefficient of aluminum 24×10^{-6} °C^{-1}, specific heat of aluminum: 900 J/kg ·°C, specific heat of copper: 387 J/kg ·°C, specific heat of steam: 2.01×10^3 J/kg ·°C, specific heat of water: 4.19×10^3 J/kg ·°C, specific heat of glass: 837 J/kg ·°C, specific heat of ice: 2.09×10^3 J/kg ·°C, latent heat of fusion of ice: 3.33×10^5 J/kg, latent heat of vaporization of water: 2.26×10^6 J/kg, density of water: $1 g/cm^3 = 10^3$ kg/m^3

B The Ideal Gas

1. Gas is contained in an 8.00 L vessel at a temperature of 20.0°C and a pressure of 9.00 atm. (a) Determine the number of moles of gas in the vessel. (b) How many molecules of gas are in the vessel?

2. Nine grams of water are placed in a 2.00 L pressure cooker and heated to 500°C. What is the pressure inside the container if no gas escapes?

3. A room of volume 80.0 m^3 contains air having an equivalent molar mass of 28.9 g/mol. If the temperature of the room is raised from 18.0 °C to 25.0°C, what mass of air (in kilograms) will leave the room? Assume that the air pressure in the room is maintained at 101 kPa.

4. Show that 1 mol of any gas (assumed to be ideal) at atmospheric pressure (101.3 kPa) and standard temperature (273 K) occupies a volume of 22.4 L.

5. Dalton's law of partial pressures states that the total pressure of a mixture of gases is equal to the sum of the partial pressures of gases making up the mixture. Give a convincing argument for this law on the basis of the kinetic theory of gases.

6. One container is filled with helium gas and another with argon gas. If both containers are at the same temperature, which gas molecules have the higher rms speed? Explain.

7. If a helium-filled balloon initially at room temperature is placed in a freezer, will its volume increase, decrease, or remain the same?

8. A cylinder contains a mixture of helium and argon gas in equilibrium at 150°C. (a) What is the average kinetic energy for each type of gas molecule? (b) What is the root-mean-square speed for each type of molecule?

9. Calculate the change in internal energy of 3.00 mol of helium gas when its temperature is increased by 2.00 K.

10. One mole of hydrogen gas is heated at constant pressure from 300 K to 420 K. Calculate (a) the energy transferred by heat to the gas, (b) the increase in its internal energy, and (c) the work done by the gas.

11. One mole of an ideal monatomic gas is at an initial temperature of 300 K. The gas undergoes an isovolumetric process, acquiring 500 J of energy by heat. It then undergoes an isobaric process, losing this same amount of energy by heat. Determine (a) the new temperature of the gas and (b) the work done on the gas.

12. During the compression stroke of a certain gasoline engine, the pressure increases from 1.00 atm to 20.0 atm. Assuming that the process is adiabatic and that the gas is ideal, with $\gamma = 1.40$, (a) by what factor does the volume change and (b) by what factor does the temperature change? (c) If the compression starts with

0.016 mol of gas at 27.0°C, find the values of Q , W, and ΔE_{int} that characterize the process.

13. Air at 20.0°C in the cylinder of a diesel engine is compressed from an initial pressure of 1.00 atm and volume of 800.0 cm^3 to a volume of 60.0 cm^3 . Assume that air behaves as an ideal gas with $\gamma = 1.40$ and that the compression is adiabatic. Find the final pressure and temperature of the air.
14. What is the number density of air at an altitude of 11.0 km (the cruising altitude of a commercial jetliner) compared with its number density at sea level? Assume that the air temperature at this height is the same as that at the ground, 20°C.
15. Four liters of a diatomic ideal gas ($\gamma = 1.40$) confined to a cylinder is subject to a closed cycle. Initially, the gas is at 1.00 atm and at 300 K. First, its pressure is tripled under constant volume. Then, it expands adiabatically to its original pressure. Finally, the gas is compressed isobarically to its original volume. (a) Draw a PV diagram of this cycle. (b) Determine the volume of the gas at the end of the adiabatic expansion. (c) Find the temperature of the gas at the start of the adiabatic expansion. (d) Find the temperature at the end of the cycle. (e) What was the net work done for this cycle?

data:

1 atm = 1.01 $\times 10^5$ Pa, 1 000 L = 1 m^3, Avogadro's constant = 6.02×10^{23} mol^{-1}, universal gas constant: 8.31 J/mol $\cdot$K