

Worksheet 1

1. State in your own terms what is the first law of thermodynamics, a closed system, an isolated system, surroundings, heat, work, and energy.
2. What is the difference between heat and temperature? Between work and energy? Between kinetic energy and potential energy?
3. Which of the following are state functions, and which are not?
 - (a) The temperature of an ice cube.
 - (b) The volume of an aerosol can.
 - (c) The amount of time required for a 10 mile bike ride.
4. Fill in the blanks. In an endothermic reaction heat is _____ and ΔH is _____. On the other hand, during an exothermic reaction heat is _____ and ΔH is _____.
5. Does heat always increase temperature? Explain.
6. True or false.
 - (a) $+q$ is when heat is absorbed into the system.
 - (b) $-q$ is when heat is released out of the system.
 - (c) $+w$ is work done by the system supplying energy.
 - (d) $-w$ is work done on the system depleting energy.
7. What is the difference between the energy change ΔU and the enthalpy change ΔH ? Which of the two is measured at constant pressure, and which at constant volume?
8. What is the difference between heat capacity and specific heat?
9. Does a measurement carried out in a bomb calorimeter give a value for ΔH or ΔU ? Explain.
10. The gas mixture inside one of the cylinders of an automobile engine expands against a constant external pressure of 0.98 atm, from an initial volume of 150 mL (at the end of the compression stroke) to a final volume of 800 mL. Calculate the work done on the gas mixture during this process, and express it in joules.
11. During his honeymoon in Switzerland, James Joule is said to have used a thermometer to measure the temperature difference between the water at the top and at the bottom of a waterfall. Take the height of the waterfall to be Δh and the acceleration of gravity g to be 9.81 m s^{-2} . Assuming that all the potential energy change $mg \Delta h$ of a mass m of water is used to heat that water by the time it reaches the bottom, calculate the temperature difference between the top and the bottom of a waterfall 100 m high. Take the specific heat capacity of water to be $4.18 \text{ J K}^{-1} \text{ g}^{-1}$.
12. A battery harnesses a chemical reaction to extract energy in the form of useful

electrical work.

(a) A certain battery runs a toy truck and becomes partially discharged. In the process, it performs a total of 117.0 J of work on its immediate surroundings. It also gives off 3.0 J of heat, which the surroundings absorb. No other work or heat is exchanged with the surroundings. Compute q , w , and ΔU of the battery, making sure each quantity has the proper sign.

(b) The same battery is now recharged exactly to its original condition. This requires 210.0 J of electrical work from an outside generator. Determine q for the battery in this process. Explain why q has the sign that it does.

13. A piece of zinc at 20.0°C that weighs 60.0 g is dropped into 200.0 g of water at 100.0°C. The specific heat capacity of zinc is $0.389 \text{ J K}^{-1} \text{ g}^{-1}$, and that of water near 100°C is $4.22 \text{ J K}^{-1} \text{ g}^{-1}$. Calculate the final temperature reached by the zinc and the water.

14. A gas expands against a constant external pressure of 2.00 atm until its volume has increased from 6.00 L to 10.00 L. During this process it absorbs 500 J of heat from the surroundings.

(a) Calculate the energy change of the gas ΔU .

(b) Calculate the work w done on the gas in an irreversible adiabatic ($q = 0$) process connecting the same initial and final states.

15. For each of the following reactions, the enthalpy change given is when the numbers of moles of reactants and products taking part in the reaction are given by their coefficients in the equation. Calculate the enthalpy change when 1.00 gram of the underlined substance is consumed or produced.

(a) $\text{Ca}(s) + \underline{\text{Br}_2(l)} \rightarrow \text{CaBr}_2(s)$ $\Delta H = -683 \text{ kJ}$

(b) $6 \text{ Fe}_2\text{O}_3(s) \rightarrow 4 \underline{\text{Fe}_3\text{O}_4(s)} + \text{O}_2(g)$ $\Delta H = +427 \text{ kJ}$

(c) $2 \underline{\text{NaHSO}_4(s)} \rightarrow 2 \text{ NaOH}(s) + 2 \text{ SO}_2(g) + \text{O}_2(g)$ $\Delta H = +806 \text{ kJ}$

16. Given the following two reactions and corresponding enthalpy changes,

$\text{CO}(g) + \text{SiO}_2(s) \rightarrow \text{SiO}(g) + \text{CO}_2(g)$ $\Delta H = +520.9 \text{ kJ}$

$8 \text{ CO}_2(g) + \text{Si}_3\text{N}_4(s) \rightarrow 3 \text{ SiO}_2(s) + 2 \text{ N}_2\text{O}(g) + 8 \text{ CO}(g)$ $\Delta H = +461.05 \text{ kJ}$

compute the ΔH of the reaction:



17. A sample of solid benzoic acid ($\text{C}_6\text{H}_5\text{COOH}$) that weighs 0.800 g is burned in an excess of oxygen to $\text{CO}_2(g)$ and $\text{H}_2\text{O}(l)$ in a constant-volume calorimeter at 25°C. The temperature rise is observed to be 2.15°C. The heat capacity of the calorimeter and its contents is known to be 9382 J K^{-1} .

(a) Write and balance the equation for the combustion of benzoic acid.

(b) Calculate the standard change in internal energy (ΔU°) for the combustion of 1.000 mol of benzoic acid to $\text{CO}_2(g)$ and $\text{H}_2\text{O}(l)$ at 25°C.

(c) Calculate the standard enthalpy change (ΔH°) for the same reaction as in part (b).

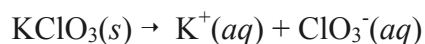
(d) The standard enthalpies of formation of $\text{CO}_2(g)$ and $\text{H}_2\text{O}(l)$ are $-393.51 \text{ kJ mol}^{-1}$ and

-285.83 kJ mol⁻¹ respectively. Calculate the standard enthalpy of formation per mole of benzoic acid.

18. Suppose 1.000 mol of argon (assumed to be an ideal gas) is confined in a strong, rigid container of volume 22.41 L at 273.15 K. The system is heated until 3.000 kJ of heat has been added. The molar heat capacity of the gas does not change during the heating and equals 12.47 J K⁻¹ mol⁻¹.

- (a) Calculate the original pressure inside the vessel (in atmospheres).
- (b) Determine q for the system during the heating process.
- (c) Determine w for the system during the heating process.
- (d) Compute the temperature of the gas after the heating, in degrees Celsius. Assume the container has zero heat capacity.
- (e) Compute the pressure (in atmospheres) inside the vessel after heating.
- (f) Compute ΔU of the gas during the heating process.
- (g) Compute ΔH of the gas during the heating process.
- (h) The correct answer to part (g) exceeds 3.000 kJ. The increase in enthalpy (which at one time was misleadingly called the “heat content”) in this system exceeds the amount of heat actually added. Why is this not a violation of the first law of thermodynamics?

19. When 1.00 g of potassium chlorate (KClO₃) is dissolved in 50.0 g of water in a Styrofoam calorimeter of negligible heat capacity, the temperature drops from 25.00 to 23.36°C. Calculate q for the water and ΔH° for the process.



20. You have made a new compound that has the formula C₄H₈N₂. You would like to measure its heat of formation. You set up the following experiment. You build a calorimeter that has a water bath in an insulated container. In that you place a piston that contains the correct molar ratios of solid carbon (graphite), H₂ gas, and N₂ gas. You then count to ten. Upon reaching to ten you shout “GO” in hopes that the atoms will all work together to form your molecule. This fails miserably. You set about to find a different method to measure the heat of formation. You put 0.1 g of your compound in the container and fill the piston with lots of oxygen gas. Then you ignite a small spark in the container your compound burns completely to form CO₂, H₂O, and N₂ (it might actually make a few other molecules but for the sake of simplicity lets just say it makes these). You then measure the change in temperature of the water bath and note that the temperature changed 0.589 °C. The heat capacity of your water bath and piston (the whole apparatus) is 5000 J °C⁻¹. You can reasonably assume the temperature is a constant 25°C

- (a) What is the enthalpy of this reaction? Give you answer in kJ mol⁻¹ (note you’ll need a balanced equation)
- (b) Can you use this information to find the enthalpy of formation for your compound? If so how and what is it?
- (c) Why did your first scheme fail? Could you improve on this method or is it always doomed to failure?

