

Kinetic Energy, Potential Energy, and First Law of Thermodynamics

- **K.E** = $\frac{1}{2} m v^2$; where m = mass in kg, and v = speed in m/s; ($\text{kg}\cdot\text{m}^2/\text{s}^2$ = Joule (J));
 - Potential energy, **P.E.** = $m\cdot g\cdot h$; where m = mass in kg; the gravitational constant, $g = 9.80 \text{ m/s}^2$, and h is height in meters;
 - First law of Thermodynamics: $\Delta E = q + w$; where ΔE is energy change for the system, q = heat absorbed or given off by the system, and $w = -p\Delta V$ is work done on or by the system. (p = pressure and ΔV = change in volume)
 - Heat (gained or lost), $q = m \times S \times \Delta T$; where, m = mass of substance; S = specific heat, and ΔT is the change in temperature. [$\Delta T = (T_{\text{final}} - T_{\text{initial}})$ can either be in Celsius or Kelvin]
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Exercises #1:

1. A 2.0-kg textbook is dropped from a height of 15 meters. Calculate the change in potential energy of the book. Is energy gained or lost or by the book? Explain.
(Answer: $\Delta U = -290 \text{ J}$)
2. (a) A golfer drives a 45-gram golf ball at a speed of 41 m/s. Calculate the kinetic energy (in Joules) of the golf ball. (b) What is the speed of a baseball (mass = 145 g) to have the same kinetic energy?
(Answer: (a) K.E. golf ball = 38 J; (b) baseball speed = 23 m/s)
3. A body of steam absorbs 379 kJ of heat and does 505 kJ of work. Calculate ΔE for the steam.
4. The evaporation of water at 100°C absorbs 40.6 kJ/mol of heat. The molar volume of liquid water at 100°C is approximately 18.0 mL. (a) What is the molar volume of steam at 100°C and 1.00 atm? (Assume ideal behavior). (b) If we assume that the steam must expand against an external pressure of 1.00 atm, how much work is done by the system? (c) What are q (heat absorbed or lost) and ΔE (the change in the internal energy for the system). Express work (w) and energy change (ΔE) in kJ. (1 L-atm = 0.1013 kJ)
(Answers: (a) molar volume = 30.6 L; (b) $w = -3.10 \text{ kJ}$; (c) $q = 40.6 \text{ kJ/mol}$; $\Delta E = 37.5 \text{ kJ}$)
5. How many kilojoules (kJ) of heat is absorbed when 250 grams of water is heated from 22°C to 100°C ? (Specific heat of water is $4.184 \text{ J/g}\cdot^\circ\text{C}$)
(Answer: $q = 82 \text{ kJ}$)
6. 50.0 g sample of hot water at 80.0°C is added to 80.0 g of cold water in a Styrofoam cup calorimeter. If the initial temperature of the cold water is 20.0°C , what is the final temperature of the mixture? (Specific heat of water = $4.184 \text{ J/g}\cdot^\circ\text{C}$; assume heat absorbed by calorimeter is negligible)
(Answer: Final temperature, $T_f = 43.1^\circ\text{C}$)
7. 100. g of iron (specific heat = $0.45 \text{ J/g}\cdot^\circ\text{C}$), initially at 95°C , is added to 50.0 g of water (specific heat = $4.184 \text{ J/g}\cdot^\circ\text{C}$) at 22°C . What is the final temperature of the mixture?
(Answer: $T_f = 35^\circ\text{C}$)

Exercises #2:

Specific Heat

1. A 46.0-g sample of copper is heated to 100.0°C and the hot metal is quickly dropped into 30.0 g of cold water in a Styrofoam cup calorimeter. The temperature of water and calorimeter was initially at 22.0°C and the final temperature of water, calorimeter, and copper is 31.5°C. (a) Calculate the total amount of heat absorbed by water and calorimeter. (b) Calculate the specific heat of copper. (Specific heat of water is 4.184 J/g.°C. Assume that heat absorbed by calorimeter is negligible.)

(Answer: (a) heat absorbed by water, $q = 1.2 \times 10^3$ J; (b) specific heat of copper = 0.38 J/g.°C)

2. 50.0 g of aluminum at 98.0°C is added 40.0 g of water in a Styrofoam cup calorimeter. If the initial temperature of water were 22.0°C, what is the final temperature of water and aluminum? (Specific heat of water is 4.184 J/g.°C and specific heat of aluminum is 0.89 J/g.°C. Assume that heat absorbed by calorimeter is negligible.)

(Answer: final temperature, $T_f = 38.0^\circ\text{C}$)

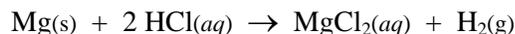
Determination of the Enthalpy of Combustion.

3. When 1.008 g of glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) is completely combusted in a “bomb” calorimeter, the calorimeter temperature increases from 21.40°C to 26.54°C. If the heat capacity of the calorimeter is 2.76 kJ/°C, calculate the enthalpy of combustion of glucose (ΔH , in kJ/mol).

(Answer: $q_{\text{cal}} = 14.2$ kJ; $q_{\text{comb}} = -14.2$ kJ; $\Delta H_{\text{comb.}} = -2540$ kJ/mol glucose)

Heat of Reaction

4. Consider the following reaction in aqueous solution:



When 0.304 g of Mg was reacted with 100.0 mL of 1.00 M HCl solution in a Styrofoam cup calorimeter, the temperature of the solution and calorimeter increased from 21.0°C to 34.5°C.

(a) How much heat is absorbed by the solution and the calorimeter, respectively. (Assume the specific heat of the solution is 4.18 J/g.°C and the heat capacity of the calorimeter is 10. J/°C.)

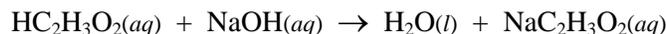
(b) Calculate the enthalpy change (ΔH , in kJ/mol) for the above reaction and indicate appropriate algebraic (+/-) sign. (c) Calculate ΔE for this reaction under standard condition (where, $P = 1.00$ atm and $T = 298$ K). ($\Delta E = \Delta H - P\Delta V$; 1 L.atm = 101.3 J)

(Answers: (a) $q_{\text{soln}} = 5660$ J; $q_{\text{cal}} = 135$ J; $q_{\text{rxn}} = -(q_{\text{soln}} + q_{\text{cal}}) = -5795$ kJ = -5.795 kJ;

(b) $\Delta H = -463$ kJ; (c) $w = -p\Delta V = -2.5$ kJ; $\Delta E = -466$ kJ)

Chem 1A
Chapter 6 Exercises

5. The enthalpy change for the following reaction is determined by carrying out the reaction in a Styrofoam cup calorimeter.



When 50.0 mL of 2.0 M acetic acid was reacted with 50.0 mL of 2.0 M NaOH in the calorimeter, the temperature of the solution and calorimeter increased from 21.0°C to 31.5°C.

(a) What is the total amount of heat (in kJ) produced by the reaction. (b) Calculate the enthalpy change (ΔH , in kJ/mol) for this reaction and indicate appropriate algebraic (+/-) sign.

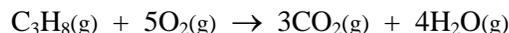
(Answers: (a) $-4.39 \times 10^3 \text{ J} = -4.39 \text{ kJ}$; (b) $\Delta H = 43.9 \text{ kJ/mol}$)

Hess's Law

6. Given the following enthalpy of formation (in kJ/mol):

$$\Delta H_f^\circ [\text{CO}_2(\text{g})] = -393.5; \quad \Delta H_f^\circ [\text{H}_2\text{O}(\text{g})] = -241.85, \quad \text{and} \quad \Delta H_f^\circ [\text{C}_3\text{H}_8(\text{g})] = -104,$$

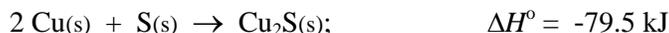
(a) Calculate the enthalpy change for the combustion of glucose:



(b) How much energy (in kJ) can be obtained if 1.00 kg of propane gas (C_3H_8) is completely combusted? (c) How much energy (in kJ) is obtained if 1.00 m³ of propane gas (C_3H_8), measured at STP, is completely combusted? ($R = 0.08206 \text{ L}\cdot\text{atm}/\text{mol}\cdot\text{K}$)

(Answers: (a) $\Delta H = -2044 \text{ kJ}$; (b) $q = -9.01 \times 10^4 \text{ kJ}$; (c) $q = -9.12 \times 10^4 \text{ kJ}$)

7. Given the following thermo-chemical equations:



Calculate the standard enthalpy of formation (in kJ/mol) of $\text{CuO}(\text{s})$.

(Answer: formation of CuO : $\text{Cu}(\text{s}) + \frac{1}{2} \text{O}_2(\text{g}) \rightarrow \text{CuO}(\text{s}); \quad \Delta H_f^\circ = -155 \text{ kJ/mol}$)

8. Given the following thermo-chemical equations:



Calculate ΔH° for the reaction: $2 \text{N}_2(\text{g}) + 5 \text{O}_2(\text{g}) \rightarrow 2 \text{N}_2\text{O}_5(\text{g})$

(Answer: $\Delta H^\circ = 28.7 \text{ kJ}$)