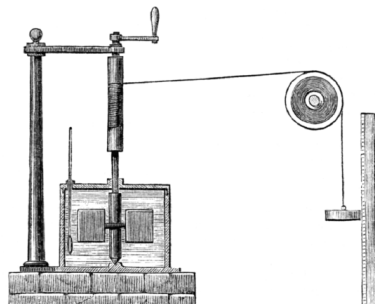


3.E: First Law of Thermodynamics (Exercises)

Q3.1

In the attempt to measure the heat equivalent of mechanical work (as Joule did in his famous experiment) a student uses an apparatus similar to that shown below:



The 1.50 kg weight is lifted 30.0 cm against the force due to gravity (9.8 N). If the specific heat of water is 4.184 J/(g °C), what is the expected temperature increase of the 1.5 kg of water in the canister?

Q3.2

1.00 mol of an ideal gas, initially occupying 12.2 L at 298 K, expands isothermally against a constant external pressure of 1.00 atm until the pressure of the gas is equal to the external pressure. Calculate Δp , q , w , ΔU , and ΔH for the expansion.

Q3.3

Consider 1.00 mol of an ideal gas expanding isothermally at 298 K from an initial volume of 12.2 L to a final volume of 22.4 L. Calculate Δp , q , w , ΔU , and ΔH for the expansion.

Q3.4

Consider 1.00 mol of an ideal gas ($C_V = 3/2 R$) Occupying 22.4 L that undergoes an isochoric (constant volume) temperature increase from 298 K to 342 K. Calculate Δp , q , w , ΔU , and ΔH for the change.

Q3.5

Consider 1.00 mol of an ideal gas ($C_p = 5/2 R$) initially at 1.00 atm that undergoes an isobaric expansion from 12.2 L to 22.4 L. Calculate ΔT , q , w , ΔU , and ΔH for the change.

Q3.6

Consider 1.00 mol of an ideal gas ($C_V = 3/2 R$) initially at 12.2 L that undergoes an adiabatic expansion to 22.4 L. Calculate ΔT , q , w , ΔU , and ΔH for the change.

Q3.7

Derive an expression for the work of an isothermal, reversible expansion of a gas that follows the equation of state (in which a is a parameter of the gas)

$$pV = nRT - \frac{an^2}{V} \quad (3.E.1)$$

from V_1 to V_2 .

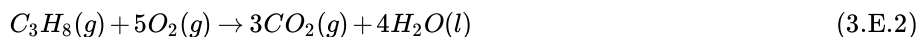
Q3.8

Use the following data [Huff, Squitieri, and Snyder, J. Am. Chem. Soc., **70**, 3380 (1948)] to calculate the standard enthalpy of formation of tungsten carbide, $WC(s)$.

Reaction	ΔH° (kJ)
$C(gr) + O_2(g) \rightarrow CO_2(g)$	-393.51
$WC(s) + 5/2O_2(g) \rightarrow WO_3(s) + CO_2(g)$	-1195.79
$W(s) + 3/2O_2(g) \rightarrow WO_3(s)$	-837.42

Q3.9

The standard molar enthalpy of combustion (ΔH_c) of propane gas is given by



with $\Delta H_c = -2220 \text{ kJ/mol}$

The standard molar enthalpy of vaporization (ΔH_{vap}) for liquid propane

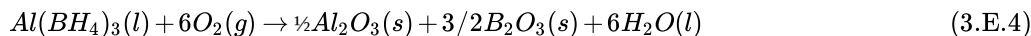


with $\Delta H_{vap} = 15 \text{ kJ/mol}$

- Calculate the standard enthalpy of combustion of liquid propane.
- Calculate the standard internal energy change of vaporization (ΔU_{vap}) for liquid propane.
- Calculate the standard internal energy change of combustion (ΔH_c) for liquid propane.

Q3.10

The enthalpy of combustion (ΔH_c) of aluminum borohydride, $Al(BH_4)_3(l)$, was measured to be -4138.4 kJ/mol [Rulon and Mason, *J. Am. Chem. Soc.*, **73**, 5491 (1951)]. The combustion reaction for this compound is given by



Given the following additional data, calculate the enthalpy of formation of $Al(BH_4)_3(g)$.

- $Al_2O_3(s)$: $\Delta H_f = -1669.8 \text{ kJ/mol}$
- $B_2O_3(s)$: $\Delta H_f = -1267.8 \text{ kJ/mol}$
- $H_2O(l)$: $\Delta H_f = -285.84 \text{ kJ/mol}$
- $Al(BH_4)_3(l)$: $\Delta H_{vap} = 30.125 \text{ kJ/mol}$

Q3.11

The standard enthalpy of formation (ΔH_f°) for water vapor is -241.82 kJ/mol at 25°C . Use the data in the following table to calculate the value at 100°C .

Substance	C_p ($\text{J mol}^{-1} \text{K}^{-1}$)
$H_2(g)$	28.84
$O_2(g)$	29.37
$H_2O(g)$	33.58

Q3.12

$\Delta C_p = (1.00 + 2.00 \times 10^{-3}T) \text{ J/K}$ and $\Delta H_{298} = -5.00 \text{ kJ}$ for a dimerization reaction



Find the temperature at which $\Delta H = 0$.

Q3.13

From the following data, determine the lattice energy of $BaBr_2$.



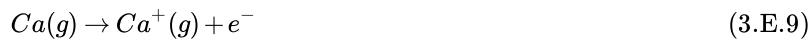
with $\Delta H_{sub} = 129 \text{ kJ/mol}$



with $\Delta H_{vap} = 31 \text{ kJ/mol}$



with $D(Br - Br) = 193 \text{ kJ/mol}$



with $1^{st} IP(K) = 589.8 \text{ kJ/mol}$



with $2^{nd} IP(K) = 1145.4 \text{ kJ/mol}$



with $1^{st} EA(Br) = 194 \text{ kJ/mol}$



with $\Delta H_f = -675 \text{ kJ/mol}$

Q3.15

Using average bond energies ([Table T3](#)) estimate the reaction enthalpy for the reaction



Contributors and Attributions

- [Patrick E. Fleming](#) (Department of Chemistry and Biochemistry; California State University, East Bay)

This page titled [3.E: First Law of Thermodynamics \(Exercises\)](#) is shared under a [CC BY-NC-SA 4.0](#) license and was authored, remixed, and/or curated by [Patrick Fleming](#).