

# Midterm answers

February 3, 2022

1. **Barometric Formula** The barometric formula is given by

$$P_h = P_0 e^{-\frac{Mgh}{RT}}$$

where  $P_h$  is the pressure at height  $h$ ,  $P_0$  is the pressure at ground level,  $M$  is the molar mass of air (28.97 g/mol),  $R$  is the gas constant, and  $T$  is the temperature. This formula has been used to approximate the elevation of mountains. Report to 3 significant figures.

(a) A hiker brings a mercury barometer to measure the height of Mount Everest. At the summit, the hiker reports the barometric pressure to be 253.0 Torr at  $-9^\circ\text{C}$ . Use the barometric formula to approximate the height of Mount Everest.

(b) Mount Everest has an official height of 8,485 meters. Is the calculated height in (a) overestimated or underestimated? Explain potential errors.

(c) Given the barometric pressure in (a), compute the partial pressure of  $\text{O}_2(\text{g})$  at the summit ( $P_{\text{O}_2}$ ) assuming that the atmosphere is made of 21%  $\text{O}_2$ . With the oxyhemoglobin dissociation curve, estimate the percent hemoglobin saturated with  $\text{O}_2$  assuming that the  $P_{\text{O}_2}$  in the blood is equivalent to the  $P_{\text{O}_2}$  at the summit.

a)  $8.50 \times 10^3$  meters

b) Overestimation. A potential error is that deriving the barometric formula assumes a constant temperature. This is not true in reality since temperature decreases going higher in altitude.

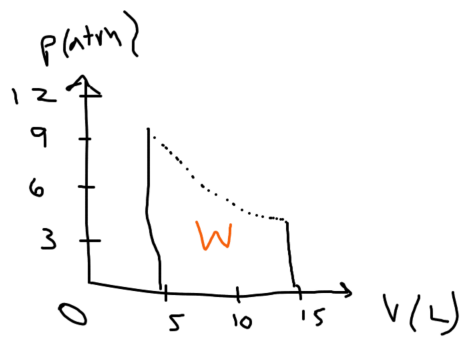
c)  $P(\text{O}_2)=53.1$  torr, around 75.0% Hb saturation

2. **Isothermal Compression** Suppose 1.87 moles of  $\text{Cl}_2(\text{g})$  at  $35^\circ\text{C}$  are compressed isothermally from a volume of 15.0L to 4.79L. Report to 3 significant figures.

(a) Sketch the process on the  $PV$  diagram. Define all variables and show what corresponds to the work ( $w$ ) done on the gas

(b) Compute the work ( $w$ ) and the heat ( $q$ ) in kJ/mol.

(c) What is the final pressure of the gas?



a)

b)  $W = -nRT \ln \frac{V_f}{V_i} = 5470 \text{ J/mol}$  and  $Q = -5470 \text{ J/mol}$

c)  $P = nRT/V_f = 9.87 \text{ atm}$

3. Explain in a few sentences what is meant by the “world energy crisis” and why this colloquial term is imprecise in the context of thermodynamics. How is the “world energy crisis” related to global warming?

Mention the 1st law of thermodynamics and greenhouse gases such as  $\text{CO}_2$  leading to less heat escaping the atmosphere.

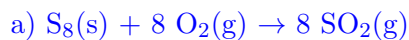
4. Quantitative combustion of 1 g of elemental sulfur,  $\text{S}_8(\text{s})$  ( $M = 256.48 \text{ g/mol}$ ), to sulfur dioxide gas increases the temperature of a bomb calorimeter from 296 K to 313.5 K. The heat capacity of the calorimeter is 530 J/K. Report all results to 4 significant figures.

a) Formulate a balanced chemical equation for the reaction including states.

b) Determine the energy of reaction.

c) Your result from b) is a good estimate for the standard energy of reaction. Using this estimate, determine the standard enthalpy of reaction assuming ideal gas behavior.

d) Estimate the standard enthalpy of formation of gaseous sulfur dioxide from these data.



b)  $Q = C\Delta T = -9.275 \text{ kJ}$

c)  $\Delta H_r = \frac{Q}{n_r} = -2379 \text{ kJ/mol}$

d)  $\Delta H_f^\circ = -297.4 \text{ kJ/mol}$

5. A bath tub contains 75 gal of water at a temperature of 110 F, which is scalding hot. Estimate the volume of 50 F cold tap water needed to bring the temperature to a more comfortable 104 F. Assume that the bath tub is thermally insulated. Water has a density of approximately  $997 \text{ kg/m}^3$  and a specific heat capacity of  $4.18 \text{ J/(g K)}$ .

$m_h$  is mass (kg) of hot bath,  $m_c$  is the mass (kg) of the cold tap water,  $C$  is heat capacity of water and  $\Delta T$  is the change in temperature

$$m_h C \Delta T_h = m_c C \Delta T_c \quad (1)$$

$$m_c = 31.450446 \quad (2)$$

The volume needed is 8.332 gallons of 50°F