

Problem set 2 – Heat Capacities, Enthalpy and Thermochemistry

Exercise Maths 2

Determine

- $\int_{T_1}^{T_2} \alpha dT$, where α is a constant,
- $\int_{x_1}^{x_2} \frac{1}{p} dx$, where p is a constant,
- $\int_{y_1}^{y_2} (g + hy) dy$, where g and h are constants,
- $\int_{z_1}^{z_2} \frac{C}{z} dz$, where C is a constant,
- $\frac{dU}{dT}$, where $U = \frac{3}{2}nRT$, with n and R constant. Hence, show that $dU = \frac{3}{2}nRdT$.

Exercise 6

When 3.0 mole of O_2 is heated at a constant pressure of 3.25 atm its temperature increases from 260 K to 285 K. Given that O_2 may be treated as a perfect (but not atomic!) gas and that its constant pressure molar heat capacity is $29.4 \text{ JK}^{-1}\text{mol}^{-1}$, calculate q , ΔH and ΔU .

Exercise 7

A 0.825 g sample of benzoic acid was ignited in a bomb calorimeter (constant V) in the presence of excess oxygen. The temperature of the calorimeter rose by 1.940 K from 298 K. The internal energy of combustion of benzoic acid is $-3251 \text{ kJ mol}^{-1}$ and its relative molecular mass is 122.

- Calculate the heat capacity of the bomb calorimeter, $C_{V,bomb}$.

In two separate experiments in the same apparatus, 0.498 g of fumaric acid ($C_4H_4O_4$) and 0.509 g of its isomer maleic acid were ignited and gave temperature rises of 0.507 K and 0.528 K respectively.

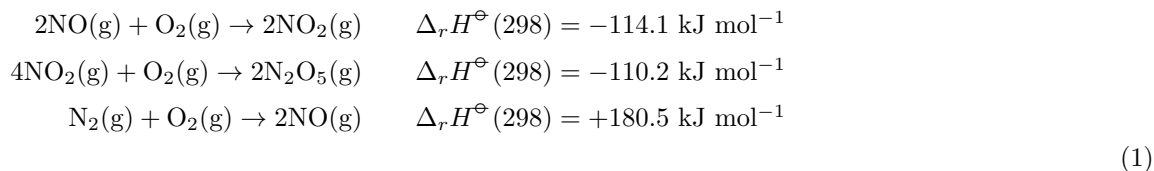
Calculate, for (i) fumaric acid and (ii) maleic acid,

- the molar internal energy of combustion, $\Delta_r U$ (hint: write down the combustion reaction);
- the molar enthalpy of combustion, $\Delta_r H$ (ignore the effect due to the small increase in temperature, and use $T = 298 \text{ K}$);
- the molar enthalpy of formation, $\Delta_f H$;
- Comment on the difference between the enthalpies of formation of the two isomers.

The standard enthalpy of formation of water is $-285.8 \text{ kJ mol}^{-1}$ and of CO_2 $-393.5 \text{ kJ mol}^{-1}$. The relative molecular mass of fumaric and maleic acid is 116.

Exercise 8

Calculate the standard enthalpy of formation of N_2O_5 at 298 K from the data below (note that the $\Delta_r H^\ominus$ are given in kJ per mole oxygen).



Exercise 9

At 298 K, the standard enthalpy of formation ($\Delta_f H^\ominus$) of $\text{NH}_3(\text{g})$ is $-46.11 \text{ kJ mol}^{-1}$. Assuming that the molar heat capacities can be represented by expressions of the form $C_{p,m} = A + BT$, with the coefficients A and B given below, calculate $\Delta_f H^\ominus$ at 1000 K.

	N_2	H_2	NH_3
$A/\text{J K}^{-1} \text{ mol}^{-1}$	28.58	27.28	29.75
$B/\text{J K}^{-2} \text{ mol}^{-1}$	$3.77 \cdot 10^{-3}$	$3.26 \cdot 10^{-3}$	$25.1 \cdot 10^{-3}$

Exercise 10

One mole of a perfect monatomic gas (with $C_V = \frac{3}{2}R$) is expanded adiabatically and reversibly to twice its initial volume, from an initial temperature of 298 K. Calculate

- the final temperature of the gas;
- the work done during the expansion.