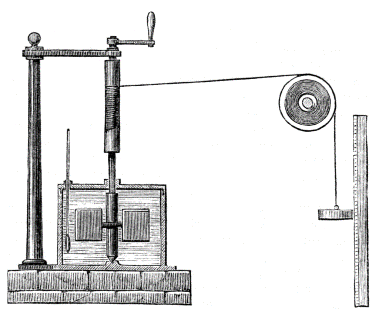
1. In the attempt to measure the heat equivalent of mechanical work (as Joule did in his famous experiment) a student uses an apparatus similar to that shown below:



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 , what is the expected temperature increase of the 1.5 kg of water in the canister?

1. 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 p, q, w, U, and H for the expansion.

The change in pressure calculation requires the use of the ideal gas law to determine the initial pressure:’

The work is given by

Because the process is isothermal, U and H are both zero. And because U is zero, q = -w. So

1. 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 p, q, w, U, and H for the expansion.

First, the change in pressure:

For an isothermal change

For an isothermal, reversible expansion of an ideal gas

And since U = 0, q = -w.

1. Consider 1.00 mol of an ideal gas (CV = 3/2 R) occupying 22.4 L that undergoes an isochoric (constant volume) temperature increase from 298 K to 342 K. Calculate p, q, w, U, and H for the change.

For an isochoric change, DV = 0. So,

Then, we can get q and DU from

And to get DH,

1. Consider 1.00 mol of an ideal gas (Cp = 5/2 R) initially at 1.00 atm that undergoes an isobaric expansion from 12.2 L to 22.4 L. Calculate T, q, w, U, and H for the change.

First, let’s find DT. To do this, we can use the ideal gas law! According to the ideal gas law,

So

For an isobaric (Dp = 0) change,

To get DU, we can use

And finally, to find w

1. Consider 1.00 mol of an ideal gas (CV = 3/2 R) initially at 12.2 L and 1.00 atm that undergoes an adiabatic expansion to 22.4 L. Calculate T, q, w, U, and H for the change.

For an adiabatic change,

Now that that is out of the way, the first thing to calculate will be the final temperature. Well, actually, the first thing to do is to find the initial temperature.

Now, to get the final temperature, we can use the relationship

So DT is

Now, let’s find w and DU.

And DH can be determined by

1. 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)

from V1 to V2.

Work for a reversible change is calculated from

And from the equation of state, we can solve for p.

So

1. 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 | Ho (kJ) |
| C(gr) + O2(g) 🡪 CO2(g) | -393.51 |
| WC(s) + 5/2 O2(g) 🡪 WO3(s) + CO2(g) | -1195.79 |
| W(s) + 3/2 O2(g) 🡪 WO3(s) | -837.42 |

To find the enthalpy of formation, we need to generate the formation reaction

from the data reactions. This can be accomplished by adding the first and third reactions to the reverse of the second reaction.

|  |  |
| --- | --- |
| C(gr) + O2(g) 🡪 CO2(g) | -393.51 kJ |
| W(s) + 3/2 O2(g) 🡪 WO3(s) | -837.42 kJ |
| WO3(s) + CO2(g) 🡪 WC(s) + 5/2 O2(g) | 1195.79 kJ |
| W(s) + C(gr) 🡪 WC(s) | -35.14 kJ |

1. The standard molar enthalpy of combustion (Hc) of propane gas is given by

C3H8(g) + 5 O2(g) 🡪 3 CO2(g) + 4 H2O(l) Hc = -2220 kJ/mol

The standard molar enthalpy of vaporization (Hvap) for liquid propane

C3H8(l) 🡪 C3H8(g) Hvap = 15 kJ/mol

1. Calculate the standard enthalpy of combustion of liquid propane.
2. Calculate the standard internal energy change of vaporization (Uvap) for liquid propane.
3. Calculate the standard internal energy change of combustion (Hc) for liquid propane.
4. The enthalpy of combustion (Hc) of aluminum borohydride, Al(BH4)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

Al(BH4)3(l) + 6 O2(g) 🡪 ½ Al2O3(s) + 3/2 B2O3(s) + 6 H2O(l)

Given the following additional data, calculate the enthalpy of formation of Al(BH4)3(g).

Al2O3(s) Hf = -1669.8 kJ/mol

B2O3(s) Hf = -1267.8 kJ/mol

H2O(l) Hf = -285.84 kJ/mol

Al(BH4)3(l) Hvap = 30.125 kJ/mol

Then

DHvap = 30.125 kJ/mol

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

|  |  |
| --- | --- |
| Substance | Cp (J mol-1 K-1) |
| H2(g) | 28.84 |
| O2(g) | 29.37 |
| H2O(g) | 33.58 |

To find DHo(100 oC), we can use

And if we assume that DCp is independent of temperature over the temperature interval,

The formation reaction for H2O(g) is

So, DCp can be calculated from

And DHo(100 oC) can be found from

1. For a reaction 2 A 🡪 A2, H298 = -5.00 kJ. The change in constant pressure heat capacity is given by

where a = 1.00 J/K and b = 2.00×10-3 J/K2. Find the temperature at which H = 0.

To solve this, we need to use the temperature dependence of the reaction enthalpy

For convenience, let’s say

and

So that

The integral isn’t too hard

Plugging this in yields

And plugging in values for a and b, and setting and T1 = 298 K:

This quadratic equation has two roots:

Clearly, we can reject the negative root. So the answer is

1. From the following data, determine the lattice energy of BaBr2.

Ca(s) 🡪 Ca(g) Hsub = 129 kJ/mol

Br2(l) 🡪 Br2(g) Hvap = 31 kJ/mol

Br2(g) 🡪 2 Br(g) D(Br-Br) = 193 kJ/mol

Ca(g) 🡪 Ca+(g) + e- 1st IP(K) = 589.8 kJ/mol

Ca+(g) 🡪 Ca2+(g) + e- 2nd IP(K) = 1145.4 kJ/mol

Br(g) + e- 🡪 Br-(g) 1st EA(Br) = 194 kJ/mol

Ca(s) + Br2-(l) 🡪 CaBr2(s) Hf = -675 kJ/mol

1. Using average bond energies (<http://chem.libretexts.org/Reference/Reference_Tables/Thermodynamics_Tables/T3%3A_Bond_Energies>) estimate the reaction enthalpy for the reaction

C2H4 + HBr 🡪 C2H5Br

From the table, we find the following data:

|  |  |
| --- | --- |
| **Bond** | **Bond Energy (kJ/mol)** |
| C-H | 413 |
| C-Br | 276 |
| H-Br | 366 |
| C-C | 614 |
| C=C | 348 |

For the reaction to occur, forming 1 mole of C2H5Br, 1 mole of each of the following bonds must be broken (H > 0) and formed (H < 0)

|  |  |  |  |
| --- | --- | --- | --- |
| **Broken** | **H (kJ/mol)** | **Formed** | **H (kJ/mol)** |
| C=C | 348 | C-C | -614 |
| H-Br | 366 | C-H | -413 |
|  |  | C-Br | -276 |

Adding all of the bond enthalpies yields the estimated reaction enthalpy: