**Homework 2- Heat Transfers**

Teacher: Paul Briard

Deadline to give me back the homework: **YOU DON’T HAVE TO GIVE ME THIS HOMEWORK**

Student name (Pinyin):

Student name (Chinese):

Student number:

**Ex.1. The molar heat capacity at constant pressure of an ideal gas.**

In a chamber where an ideal gas exert a force to a piston, we are interested by a transformation of the ideal gas at constant pressure (transformation means “process”, i.e. to come from an initial state to a final state). This system is closed (the number of moles of gas stay constant during the transformation). a) Describe the infinitesimal heat transfer between the system and its surrounding during the transformation in terms of , , and an infinitesimal change of the temperature of the system.

b) Then, describe an infinitesimal change of internal energy during a transformation at constant pressure in terms of , where is an infinitesimal change of the volume of the system.

c) Considering an ideal gas, describe in terms of (take care that here and are constant). Then describe the infinitesimal work done by the system to its surrounding in terms of .

d) Using your results of part (b) and (c), you obtain an expression of the infinitesimal change of internal energy in terms of . Conclude with the expression of in terms of the number of degrees of freedom (about the expression of the molar heat capacity at constant volume , you can use this expression and don’t have to demonstrate it ).

**Solution:**

a)

b)

Where is the work done by the system to its surroundings:

For a transformation at constant pressure:

c)

Ideal gas law:

Thus,

Here, is constant and is constant, thus:

We obtain the infinitesimal work done by the system on its surroundings during a transformation at constant pressure:

d)

For a transformation at constant pressure:

We obtain:

For any transformation, the infinitesimal change of internal energy is :

where is the molar heat capacity at constant volume of the ideal gas:

We obtain the expression of the molar heat capacity at constant pressure:

**Ex. 2. The adiabatic process of an ideal gas**

We define the ratio of heat capacities of an ideal gas as follows:

where is the molar heat capacities at constant pressure and is the molar heat capacities at constant volume. For a gas, .An adiabatic transformation is a particular process where the system has no heat transfer with its surrounding, i.e.: the heat and the infinitesimal heat . We consider an ideal gas of constant number of moles , temperature (take care that it can change, “adiabatic” don’t means “the temperature is constant”), pressure , volume . At initial state, its temperature is its volume is and its pressure is .

a) Describe an infinitesimal change of internal energy of the ideal gas in terms of the infinitesimal change of volume of gas, during an adiabatic process.

b) From your previous result, describe a relationship involving the ratios and .

c) An interesting relationship between and the ideal gas constant is (you can verify it by yourself):

Use this property in your previous result.

d) By integration, you obtain a relationship between the temperature and the volume of the ideal gas, and (we consider the number of degrees of freedom during the process of the ideal gas is constant, thus is constant).

e) Describe a relationship between the pressure and the volume of an ideal gas during an adiabatic transformation.

f) Describe the work done by the ideal gas to its surroundings in terms of and change of temperature during an adiabatic transformation (and considering the system is closed and its number of degrees of freedom is constant, which means is constant).

Help: ,

a)

During an adiabatic transformation, , i.e.:

We consider an ideal gas: , thus, during an adiabatic transformation,

b)

For any transformation, the infinitesimal change of internal energy is:

c)

We obtain,

d)

By integration ( is constant), we obtain:

Finally, during an adiabatic process,

If we consider the initial temperature and the initial volume , during the adiabatic process:

e)

Ideal gas law: , we obtain:

The ideal gas constant is constant, and the number of moles is here constant (system closed), thus we obtain:

If we consider the initial pressure and the initial volume , during the adiabatic process:

For an adiabatic transformation, the change of internal energy is:

where is the work done by the system to its surroundings

For any transformation,

The system is closed ( is constant), and is constant, thus:

We obtain:

**Ex. 3. Work during an isothermal expansion**

We consider a case of isothermal expansion of a gas which move a piston (“isothermal” means “the temperature of the gas is constant”. The number of moles of gas is also constant (system closed).

a) Describe the work done by the ideal gas on the piston in this situation, in respect to the number of gas moles , the gas temperature , the initial volume and the final volume .

b)Then, describe the work done in respect to, T, the initial pressure and the final pressure .

a)

The infinitesimal work done by the ideal gas on the piston is:

Ideal gas law: , thus:

The work done during the isothermal expansion (is constant, is constant):

b)

Ideal gas law: : ,and here and is constant, thus:

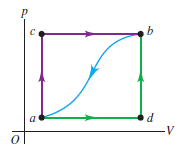
**Ex. 4**

When a system is taken from state a to state b in figure along the path acb, 90.0 J of heat flows into the system and 60.0 J of work is done by the system on its surroundings.

(a) First we are interested by a transformation from state *a* (pressure , volume , temperature ) to state (pressure , volume , temperature ). Describe the change of internal energy of the system during the transformation in terms of , , , if the system is considered as an ideal gas (considering the system is closed and the molar heat capacity at volume constant is constant). Does the change of internal energy depends to the “path” from a to b ?

(b) How much heat flows into the system along path adb if the work done by the system is 15.0 J?

(c) When the system is returned from b to a along the curved path, the absolute value of the work done by the system is 35.0 J. Does the heat flows from the system to its surroundings or does the heat flows from the surroundings toward the system ? How much heat ?



**Solution**

a)

For an ideal gas, the change of internal energy is:

Here, is constant (system closed) and is constant (because the number of degrees of freedom is constant).

Ideal gas law: thus and

The change of internal energy don’t depends to which path is considered.

b)

where is the work done by the system to its surroundings. The change of internal energy is the same for any path. From the path acb, we obtain:

About the path adb:

We obtain:

c)

from b to a by the curved path

Take care that from b to a, the direction of the path is from the right to the left, which means

The heat is then

, which means the heat flows from the system toward its surroundings.