Explanation Chapter 9

9.1 Addition of heat at constant pressure to a gas result in:
a) Raising its temperature
b) Raising its pressure
c) Raising its volume
d) Raising its temperature and doing external work
e) Doing external work
Ans: D. Increase in internal energy is related to the increase in temperature and increase in volume is related to the external work. When pressure remains constant, the volume must expand to accommodate for that, so the work is done to expand the material.

9.2 In an isothermal process, the internal energy of an ideal gas:
a) Increases
b) Decreases
c) Remains constant
d) May increase/decrease, depending on the properties of gas.
e) Is unpredictable
Ans: C. In an isothermal process the temperature remains constant. The temperature depends on the movement of the molecules which is related to the kinetic energy of the modules. This also makes up the internal energy of a system.

9.3 Gases have:
a) Only one value of specific heat.
b) Only two values of specific heat
c) Only three values of specific heat
d) None of the above
Ans: C. Gases have specific heat capacity at constant pressure (C_p) and constant volume (C_v)

9.4 Air at 100 kPa and 300 K is compressed steadily by a 20kW compressor to 300 kPa. The air temperature is maintained constant at 300 K due to heat transfer to the surrounding medium at 273K. What is the rate of heat loss of the air?
(Hint: $dh = c_p dT$)
a) -20 kW
b) -10 kW
c) 10 kW
d) 15 kW
e) 20 kW

Ans: A. Remember that work added to the system is considered negative as is the heat rejected by it. A possible error here is that $\dot{Q}_{out}$ was used instead of of $\dot{Q}_{net}$ as specified by the exercise. The variables are not interchangeable. A trick of this question is to notice that you cannot use the equation given in the hint to directly calculate the change of enthalpy with respect to the surroundings.
The conservation of energy equation should be used to calculate the conversion of work into heat.

$$\dot{m}(w + q + k_e + p_e + h)_{in} = \dot{m}(w + q + k_e + p_e + h)_{out}$$

For a compressor, changes in kinetic and potential energy are negligible. Air is kept to the same temperature, so: $dh = c_p dT = 0$

Which leaves us with: $\dot{Q}_{net} = \dot{W}_{net} = \dot{W}_{out} - \dot{W}_{in}$

A compressor does not deliver any kind of work output, so the final equation is found to be:

$$\dot{Q}_{net} = -\dot{W}_{in} = -20kW$$

Work added to the system is considered negative as is the heat rejected by the system.

9.5 Under what conditions is the ideal-gas assumption suitable for real gases?
a) High temperatures
b) Low pressures
c) Low densities
d) High densities
e) Isentropic conditions

Ans: A, B, C. A gas can be treated as ideal gas when it is at higher temperatures or low pressures relative to its critical temperature and pressure. Because, at high temperatures and low pressures, the density of gas decreases and at low densities real gases behave as ideal gases.

9.6 Is the energy required to heat air from 295 to 305 K the same as the energy required to heat it from 345 to 355 K? Assume the pressure remains constant in both cases.
a) The heat transfer will be the same since ΔT is the same.
b) The heat transfer will be the same since pressures remain constant and c_p will the same for both cases.
c) The heat transfer will be greater for 345 to 355 K because c_p is greater at higher temperatures.
d) The heat transfer will be greater for 295 to 305 K because at lower temperatures the density of air increases.

Ans: C. The expression for rate of heat transfer is: $\dot{Q} = \dot{m}(h_2 - h_1) = \dot{m}c_p\Delta T$.
Here, mass flow is$\dot{m}$, specific heat capacity is c_p and change in temperature is ΔT. If the specific gas constant c_p remains constant as pressure remains constant, then the heat transfer will be the same since ΔT is the same. But c_p is higher (see A-2) at higher temperatures. Therefore, the heat required will be higher for 345K to 355 K.

9.7 A piston cylinder device contains an ideal gas. The gas undergoes two successive cooling processes by rejecting heat to the surroundings. First the gas is cooled at constant pressure until $T_2 = \frac{3}{4}T_1$. Then the piston is held stationary while the gas is further cooled to $T_3 = \frac{1}{2}T_1$, where all temperatures are in K. The ratio of the final volume to the initial volume of the gas is:

a) 0.25
b) 0.50
c) 0.67
d) 0.75
e) 1.0

Ans: D. First, it should be noted that there is no change in volume between the 2nd and the 3rd state since the piston is held stationary. Therefore, $\frac{V_2}{V_1} = \frac{V_3}{V_1}$ holds.

Because process 1-2 has a constant volume, the following equation holds:

$$\frac{V_2}{V_1} = \frac{T_2}{T_1} = \frac{3/4T_1}{T_1}$$

So, the ratio of the final volume to the initial volume is:

$$\frac{V_3}{V_1} = 0.75$$

9.8 The work done on the gas by the piston is:

a) $R\frac{T_1}{4}$
b) $c_v\frac{T_2}{2}$
c) $c_p\frac{T_1}{2}$
d) $\frac{(c_p+c_v)T_1}{4}$
e) $\frac{c_v(T_1+T_3)}{2}$

Ans: A. Process 2-3 is a constant volume process, so:

$$W_{2-3} = 0$$

Process 1-2 is a constant pressure process, so:

$$W_{1-2} = P(V_2 - V_1)$$
$$W_{1-2} = R(T_2 - T_1)$$
$$W_{1-2} = R\left(\frac{3}{4}T_1 - T_1\right)$$
$$W_{1-2} = \frac{RT_1}{4}$$

Combining the work of the 2 processes gives:

$$W = W_{1-2} + W_{2-3} = \frac{RT_1}{4} + 0$$

9.9 An ideal gas has a gas constant $R = 0.3kJ/(kgK)$ and a constant volume specific heat $c_v = 0.7kJ/(kgK)$. If the gas has a temperature change of $100°C$, what is the change in enthalpy?

a) 30
b) 70
c) 100
d) Insufficient information to determine

Ans: C. The change in enthalpy is given by:

$$\Delta h = c_p \Delta T = (c_v + R)\Delta T = 100\ kJ/kg$$

9.10 An ideal gas has a gas constant $R = 0.3kJ/(kgK)$ and a constant volume specific heat $c_v = 0.7kJ/(kgK)$. If the gas has a temperature change of $100°C$, what is the change in internal energy in kJ/kg?

a) 30
b) 70
c) 100
d) Insufficient information to determine

Ans: B. The change in internal energy is given by: $\Delta u = c_v \Delta T = 70kJ/kg$.

9.11 An ideal gas has a gas constant $R = 0.3kJ/(kgK)$ and a constant volume specific heat $c_v = 0.7kJ/(kgK)$. If the gas has a temperature change of $100°C$, what is the work done in kJ/kg?

a) 30
b) 70
c) 100
d) Insufficient information to determine

Ans: D. The work done cannot be determined since there is no information on volume change or the pressure and it can neither be determined from the energy balance relation. This is because we do not know the exact process (path) of how temperature change was achieved, it could be constant volume, constant pressure. The work is path dependent, and it would be different for each of these scenarios.

9.12 An ideal gas has a gas constant $R = 0.3kJ/(kgK)$ and a constant volume specific heat $c_v = 0.7kJ/(kgK)$. If the gas has a temperature change of $100°C$, what is the heat transfer in kJ/kg?

a) 30
b) 70
c) 100
d) Insufficient information to determine

Ans: D. The heat transfer also cannot be determined for the same reasoning the work cannot be found. We do not know what exact process took place and heat transfer is different for different processes.

9.13 An ideal gas has a gas constant $R = 0.3kJ/(kgK)$ and a constant volume specific heat $c_v = 0.7kJ/(kgK)$. If the gas has a temperature change of $100°C$, what is change in Pv in kJ/kg?

a) 30

b) 70

c) 100

d) Insufficient information to determine

Ans: A. The change in P-v is given by the following formula: $\Delta(PV) = R\Delta T = 30kJ$