1. a) The molar specific heat of a diatomic gas is measured at constant volume and found to be 29.1 J/(mol K). What are the types of energy that are contributing to the molar specific heat?
    - i. Translation only
    - ii. Translation and rotation only
    - iii. Translation and vibration only
    - [✓ iv.] Translation, rotation and vibration

    Give a one sentence explanation of your answer.

    b) Why does a diatomic gas have a greater energy content per mole than a monatomic gas at the same temperature?

a) $R = 8.31 \ \mathrm{J/mol\,K}$

$C_m = \frac{xR}{2}$ where x is the number of degrees of freedom

$$x = \frac{2C_m}{R} = \frac{2(29.1 \ \mathrm{J/mol\,K})}{8.31 \ \mathrm{J/mol\,K}} = 7$$

The molar heat capacity of this gas is $\frac{7R}{2}$, which according to the equipartition theorem means there are 7 degrees of freedom that contribute to the internal energy of each molecule: 3 from translation, 2 from rotation and 2 from vibration.

b) Because the internal energy of the gas (the energy content) depends on the number of degrees of freedom of the molecules. A monatomic gas only has 3 degrees of freedom (from translation), while a diatomic gas has 5 degrees of freedom (neglecting vibration) or 7 (including vibration).

1.12 a) N_2 gas

molar mass of N : 14.01 g/mol, so for N_2, $M = 2 \times 14.01$ g/mol $= 28.02$ g/mol

neglecting vibrations, N_2 has 5 degrees of freedom

heat capacity per mole : $C_m = \frac{5}{2}R = \frac{5}{2}(8.315 \text{J/Kmol}) = 20.8 \text{ J/Kmol}$

heat capacity per gram : $\frac{C_m}{M} = \frac{20.8 \text{ J/K mol}}{28.02 \text{ g/mol}} = 0.742 \text{ J/Kg} = c_s$

this is close to the experimental value of 0.743 J/Kg

b) CO_2 gas, assuming the molecule is linear (O-C-O)

M_c : 12.01 g/mol

M_o : 16.0 g/mol

M_{CO_2} : $M_c + 2M_o = 44.01$ g/mol

neglecting vibrations and rotations about the molecular axis, CO_2 has five degrees of freedom

$$C_m = \frac{5}{2}R = 20.8 \text{ J/Kmol}$$

$$c_s = \frac{C_m}{M_{CO_2}} = \frac{20.8 \text{ J/Kmol}}{44.01 \text{ g/mol}} = 0.47 \text{ J/Kg}$$

this is smaller than the experimental value of 0.648 J/Kg

c) Ag, M_{Ag} : 107.9 g/mol

$$C_m = 3R = 3(8.315 \text{J/K mol}) = 24.95 \text{ J/Kmol}$$

$$c_s = \frac{C_m}{M_{Ag}} = \frac{24.95 \text{ J/Kmol}}{107.9 \text{ g/mol}} = 0.231 \text{ J/Kg}$$ close to the experimental value

d) Si, M_{Si} : 28.09 g/mol

$$C_m = 24.95 \text{ J/Kmol}$$

$$c_s = \frac{C_m}{M_{Si}} = \frac{24.95 \text{ J/Kmol}}{28.09 \text{ g/mol}} = 0.88 \text{ J/Kg}$$ larger than the experimental value