Thermodynamics [DPP-3] (Solutions)

Topic: Heat Capacity

I didn't talk—I showed through action! Assignment completed like a true ninja!

Q1. 5 moles of oxygen are heated at constant volume from 10°C to 20°C. What will be the change in internal energy of gas? Given $C_p = 7.03$ cal mol^{-1}K^{-1}, $R = 2$ cal mol^{-1}K^{-1}.

Conceptual Approach

At constant volume, $\Delta U = nC_v\Delta T$. We first calculate $C_v = C_p - R$ and then substitute.

Step-by-step Solution

$$C_v = 7.03 - 2 = 5.03\,\text{cal mol}^{-1}\text{K}^{-1}$$

$$\Delta U = nC_v\Delta T = 5 \times 5.03 \times (20 - 10)$$

$$\Delta U = 251.5\,\text{cal}$$

Final Answer: $\Delta U = 251.5$ cal.

Q2. A gas expands from 3 dm^3 to 5 dm^3 against 3 atm. Work done is used to heat 10 mol of water at 290 K. Find final temperature of water. ($c = 4.184$ J g^{-1}K^{-1}).

Conceptual Approach

Work done by gas = Heat absorbed by water. $w = -P\Delta V$. Convert to J and use $q = mc\Delta T$.

Step-by-step Solution

$$\Delta V = 2\,\text{L},\ P = 3\,\text{atm}$$

$$w = -3 \times 2 = -6\,\text{L·atm}$$

Convert: $1\,\text{L·atm} = 101.32$ J

$$w = -6 \times 101.32 = -608\,J$$

Heat absorbed = 608 J. Mass of 10 mol water = $10 \times 18 = 180$ g.

$$\Delta T = \frac{q}{mc} = \frac{608}{180 \times 4.184} \approx 0.81\,K$$

$$T_f = 290 + 0.81 \approx 290.8\,K$$

Final Answer: $T_f \approx 290.8$ K.

Q3. Calculate heat required to raise 13.5 g Al from 300 K to 400 K. $c = 0.9$ J g^{-1}K^{-1}.

Solution

$$q = mc\Delta T = 13.5 \times 0.9 \times (400 - 300)$$

$$q = 13.5 \times 0.9 \times 100 = 1215\,J$$

Final Answer: 1215 J.

Q4. When 229 J heat is supplied at constant pressure to 3 mol Ar(g), $T = 2.55$ K. Find C_v.

Solution At constant pressure:

$$q = nC_pT \implies C_p = \frac{229}{3 \times 2.55} = 29.9\, J\, mol^{-1}K^{-1}$$

$$C_v = C_p - R = 29.9 - 8.314 = 21.6\, J\, mol^{-1}K^{-1}$$

Final Answer: $C_v \approx 21.7$ J mol^{-1}K^{-1} (Option c).

Q5. The correct relation between C_p and C_v is

Final Answer: $C_p - C_v = R$ (Option c).

Q6. A gas has $S_v = 0.075$ cal g^{-1}K^{-1}, mol wt=40. Find atomicity.

Solution Molar $C_v = 0.075 \times 40 = 3$ cal mol^{-1}K^{-1} Convert to R units: $R = 2$ cal mol^{-1}K^{-1}

$$\frac{C_v}{R} = \frac{3}{2} = 1.5$$

For ideal gas, $C_v = \frac{f}{2}R$. So $f = 3$, monoatomic.
Final Answer: Atomicity = 1 (Option a).

Q7. C_v of monoatomic gas = ?

Final Answer: $\frac{3}{2}R$ (Option a).

Q8. Molar heat capacity of water in equilibrium with ice at constant pressure is ?

Final Answer: ∞ (Option b).

Q9. At triple point solid, liquid, vapour present. Average KE of molecule is ?

Final Answer: Same in all three states (Option d).

Q10. Difference between $C_p(H_2)$ and C_v(He) ?

Solution For H_2: $C_p = \frac{7}{2}R$. For He: $C_v = \frac{3}{2}R$. Difference = $2R$.
Final Answer: $2R$ (Option b).

Q11. Which of the following can be correct?

Final Answer: All of these (Option d).

Q12. Volume of gas doubled. Specific heat ?

Final Answer: Remains same (Option c).

Q13. 5.6 L gas at STP needs 52.25 J for 10°C rise at constant volume. Gas is ?

Solution 5.6 L = 0.25 mol at STP.

$$C_v = \frac{q}{nT} = \frac{52.25}{0.25 \times 10} = 20.9\, Jmol^{-1}K^{-1}$$

Compare with gases: He: 12.5 J, H_2: 20.8 J, CO_2: 28 J(if we include vibrational motion), NO_2: 30 J.
Final Answer: H_2 (Option b). In this question H_2 and CO_2 should be the answer . But more correct answer is H_2.

Q14. For 1 mol ideal gas: relation between C_p and C_v ?

Final Answer: $C_p - C_v = R$ (Option a).
