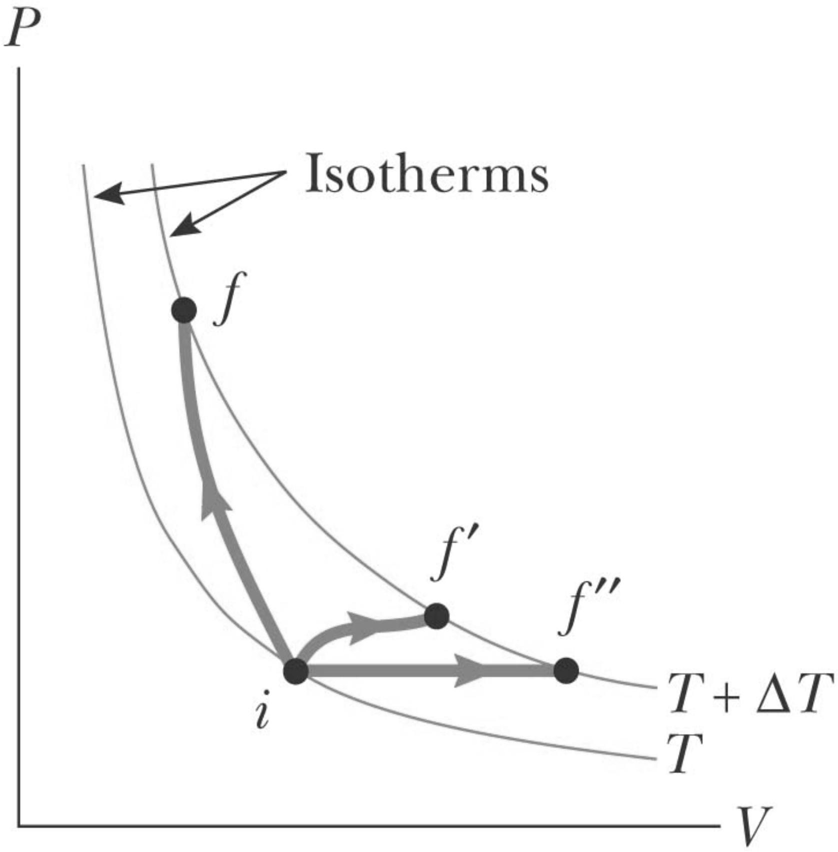
Molar Specific Heat

- Several processes can change the temperature of an ideal gas
- Since ΔT is the same for each process, ΔE_{int} is also the same
- The heat is different for the different paths
- The heat associated with a particular change in temperature is **not** unique



Molar Specific Heat

- We define specific heats for two processes that frequently occur:
  - Changes with **constant pressure**
  - Changes with **constant volume**
- Using the number of moles, *n*, we can define molar specific heats for these processes

Molar Specific Heat

- Molar specific heats:
  - $Q = nC_V \Delta T$ for constant-volume processes
  - $Q = nC_P \Delta T$ for constant-pressure processes
- Q (constant pressure) must account for both the increase in internal energy and the transfer of energy out of the system by work
- $Q_{\text{constant } P} > \mathrm{Q}_{\text{constant } V}$ for given values of n and ΔT

Ideal Monatomic Gas

- A monatomic gas contains one atom per molecule
- When energy is added to a monatomic gas in a container with a fixed volume, all of the energy goes into increasing the translational kinetic energy of the gas
  - There is no other way to store energy in such a gas

Ideal Monatomic Gas

- Therefore, $\Delta E_{\text{int}} = 3/2\ nR\Delta T$

  ΔE is a function of ΔT only
- In general, the internal energy of an ideal gas is a function of T only
  - The exact relationship depends on the type of gas
- At constant volume, $Q = \Delta E_{\text{int}} = nC_V\,\Delta T$
  - This applies to all ideal gases, not just monatomic ones

Monatomic Gases

- Solving for C_V gives $\boldsymbol{C_V = 3/2\ R}$ = 12.5 J/mol · K
  - For all monatomic gases
  - This is in good agreement with experimental results for monatomic gases
- In a constant-pressure process, $\Delta E_{\text{int}} = Q - W$ and

$$\boldsymbol{C_P - C_V = R}$$

  - **This also applies to any ideal gas**
  - $C_P = 5/2\ R = 20.8$ J/mol · K

Ratio of Molar Specific Heats

- We can also define

$$\gamma = \frac{C_P}{C_V} = \frac{5R/2}{3R/2} = 1.67$$

- Theoretical values of C_V , C_P , and *g* are in excellent agreement for monatomic gases
- But they are in serious disagreement with the values for more complex molecules
  - Not surprising since the analysis was for monatomic gases

Adiabatic Processes for an Ideal Gas

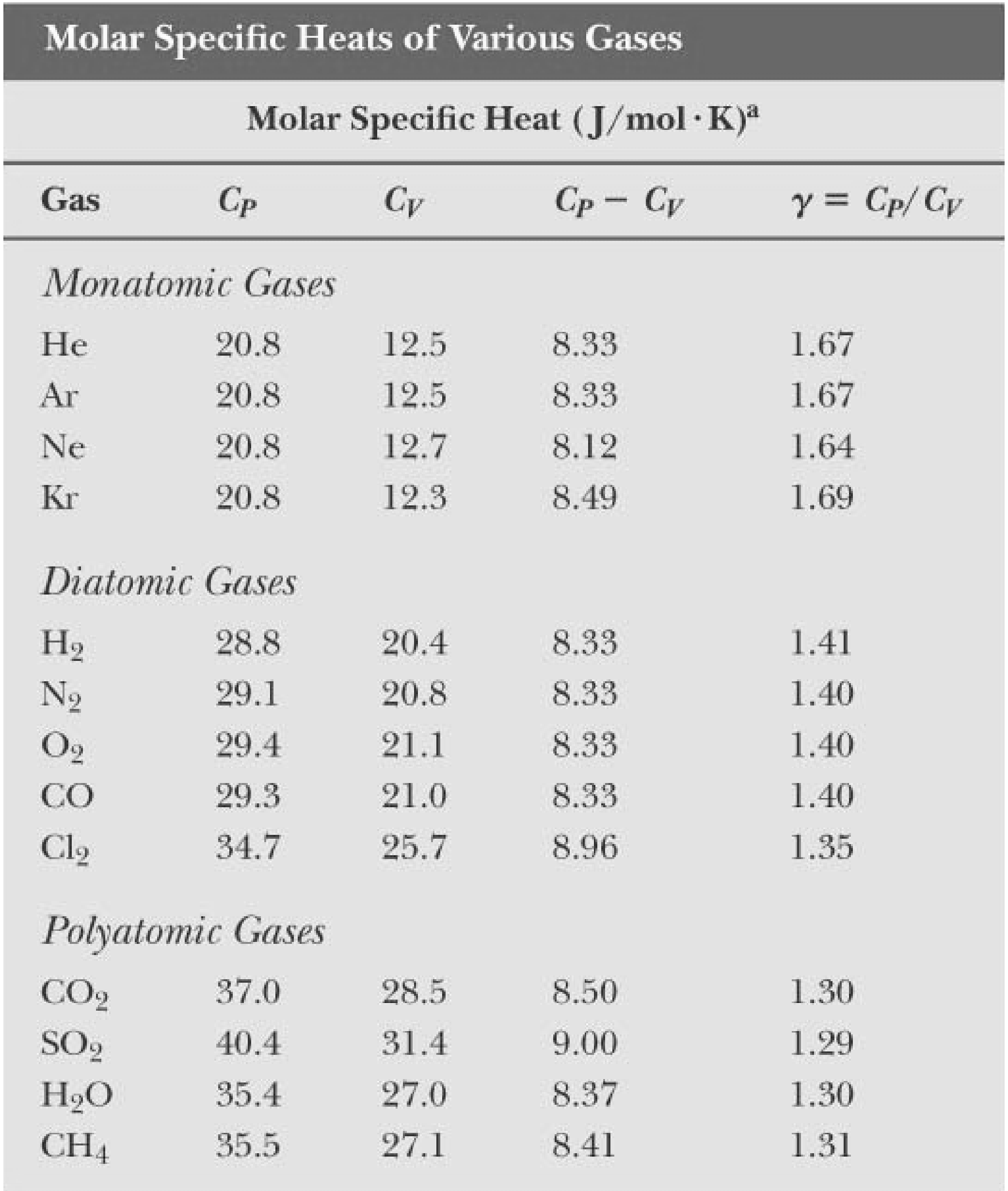
- Assume an ideal gas is in an equilibrium state and so $PV = nRT$ is valid
- The pressure and volume of an ideal gas at any time during an adiabatic process are related by

$$\boldsymbol{PV^{g} = \text{constant}}$$

g **=** $\boldsymbol{C_P / C_V}$ is assumed to be constant during the process

- All three variables in the ideal gas law (P, V, T) can change during an adiabatic process

Values of Molar Specific Heats



Molar Specific Heats of Various Gases

Gas	Molar Specific Heat (J/mol · K)[a] C_P	C_V	$C_P - C_V$	$\gamma = C_P/C_V$
Monatomic Gases				
He	20.8	12.5	8.33	1.67
Ar	20.8	12.5	8.33	1.67
Ne	20.8	12.7	8.12	1.64
Kr	20.8	12.3	8.49	1.69
Diatomic Gases				
H_2	28.8	20.4	8.33	1.41
N_2	29.1	20.8	8.33	1.40
O_2	29.4	21.1	8.33	1.40
CO	29.3	21.0	8.33	1.40
Cl_2	34.7	25.7	8.96	1.35
Polyatomic Gases				
CO_2	37.0	28.5	8.50	1.30
SO_2	40.4	31.4	9.00	1.29
H_2O	35.4	27.0	8.37	1.30
CH_4	35.5	27.1	8.41	1.31