Thermo & Quantum Mechanics

Thermodynamics Equations

- $\Delta U = Q+W$ 1st Law
- $W = -\int PdV$
- $dQ = TdS$ for reversible processes
- $\Delta U = mC_v\Delta T$
- $\Delta S_{universe} \geq 0$ 2nd Law
- $H = U+PV$ Enthalpy
- $\Delta H = mC_p\Delta T$
- $PV = nRT = nk_BN_AT$ Ideal gas law

Thermodynamics

Problem 1

O_2 gas goes through the cycle A -> B -> C -> A as shown in the figure. If the gas goes through one full cycle, which of the following is true for the gas?

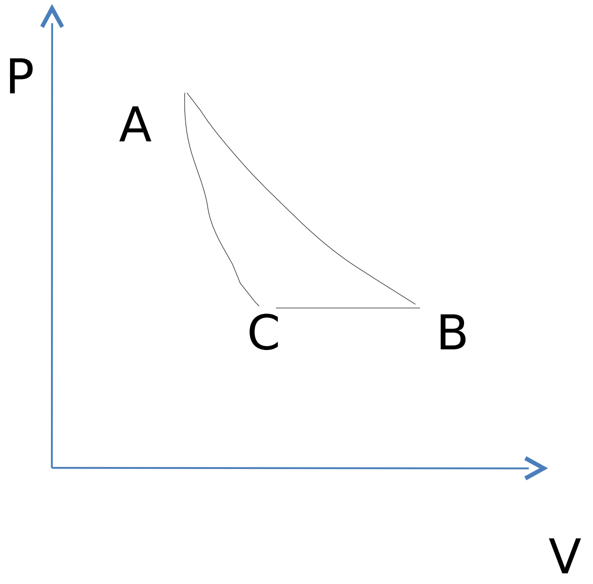
(a) $\Delta U = \Delta H = 0$, $\Delta S > 0$, $W>0$, $Q<0$

(b) $\Delta U = \Delta H = 0$, $\Delta S > 0$, $W<0$, $Q>0$

(c) $\Delta U = \Delta H = \Delta S = 0$, $W<0$, $Q>0$

(d) $\Delta U = \Delta S = 0$, $\Delta H > 0$, $W>0$, $Q<0$

(e) $0<\Delta U<\Delta H$, $\Delta S > 0$, $W<0$, $Q>0$



Thermodynamics

Problem 2

A container is separated into 2 equal volumes by a membrane. The right side of the membrane is filled with 1 mole of N_2 gas, and the left side is filled with 1 mole of $C0_2$ gas. The membrane is broken and the two gasses are allowed to mix. What is the change in entropy?

(a) 0

(b) 2R Ln(2)

(c) R Ln(2)

(d) $C_v\ \Delta T/T$

(e) $C_p\ \Delta T/T$

Quantum Mechanics

- Schrodinger equation

$$-\frac{\hbar^2}{2m}\nabla^2\Psi + V\Psi = E\Psi$$

- Uncertainty Principle

$$\sigma_A^2\sigma_B^2 \ge \left(\frac{1}{2i}\left\langle[\hat{A},\hat{B}]\right\rangle\right)^2$$

- Harmonic oscillator
  - $H = \frac{p^2}{2m} + \frac{1}{2}m\omega^2 = \hbar\omega(a^* a + \frac{1}{2})$

$$E = \hbar\omega(n + \frac{1}{2})$$

- Infinite Square Well

$$\Psi_n = \sqrt{\frac{2}{a}}\sin(\frac{n\pi}{a}x)$$

- Delta function potential
- Angular Momentum Operators
- Hydrogen (like) Atom

$$E_n = -\left[\frac{\mu}{2\hbar^2}\left(\frac{Ze^2}{4\pi\varepsilon_0}\right)^2\right]\frac{1}{n^2}$$

- 1st order perturbation
- So on …

Quantum Mechanics

Problem 1

A diatomic molecule is initially in the state $\Psi(\theta, \varphi) = (5Y_1^{1} + 3Y_5^{1} + 2Y_5^{-1})/(38)^{1/2}$, where Y_l^{m} is the spherical harmonic. What is the probability of measuring m=1?

(a) 25/38

(b) 3/38

(c) 8/(38)1/2

(d) 34/38

(e) 4/5

Quantum Mechanics

Problem 2

A molecule is in the state $\Psi(\theta, \varphi) = (3/4\pi)1/2 \sin\theta \cos\varphi$. What is the expectation value for the operator $O = [L_+,L_-]$?

(a) 0

(b) $\hbar^2$

(c) $2\hbar^2$

(d) $3/2\ \hbar^2$

(e) $3\hbar^2$

Quantum Mechanics

Problem 3

The operator O=(**a***+**a**)2 operates on the a wave quantum harmonic oscillator in state |n=4>. What is the expectation value for this operator?

(a) 9

(b) 8

(c) 0

(d) 2π

(e) 4

Quantum Mechanics

Problem 4

Muonic hydrogen is when a muon instead of an electron is orbiting the proton. The muon is approximately 200 time heavier than the electron. What is the ground state energy of a muonic hydrogen?

(a) -2448 eV

(b) -13.6 eV

(c) Muons decay, and therefore muonic hydrogen does not exist.

(d) -2720 eV

(e) 27200 eV

Quantum Mechanics

Problem 5

Two hydrogen atoms with spin $\mathbf{S}_1$ and $\mathbf{S}_2$ have the interaction Hamiltonian H = -a $\mathbf{S}_1 \cdot \mathbf{S}_2$ where J>0. The atoms are placed in a uniform magnetic field B. What is their ground state energy?

(a) $-(J/2)[(S_1+S_2)(S_1+S_2+1)-S_1(S_1+1)-S_2(S_2+1)]$

(b) $-\gamma BS_1 - \gamma BS_2$

(c) $-\gamma BS_1 - \gamma BS_2 -(J/2)[(S_1+S_2)(S_1+S_2+1)-S_1(S_1+1)-S_2(S_2+1)]$

(d) $-\gamma BS_1 - \gamma BS_2 - J[S_1(S_1+_1)+S_2(S_2+1)]$

(e) $-\gamma BS_1 - \gamma BS_2 - JS_1S_2$

Answers

Thermo

1) C
2) B

QM

1) D
2) A
3) A
4) A
5) C