

Chemistry 342
First Exam
February 4, 2005
2:00 PM in C6 Lecture Center

Write all work you want graded in the spaces provided. Both the logical solution to the problem and the answer to the question are required. Final numerical values receive only small additional credit. What is required is an answer in terms of the original numerical data, including all numerical values and units of conversion factors. Use no intermediate calculated numbers, except where such numbers arise from answers to previous parts. The solution has to be worked out in the form of complete equations, with justification or basis for the use in the specific problem.

Example:

Solutions	
Step 1	$d\mathbf{w} = -p_{op}dV$ definition $d\mathbf{U} = C_V dT + (\partial\mathbf{U}/\partial V)_T dV$ Apply $dV = 0$ (constant volume) $\therefore \mathbf{w} = 0$ $\therefore d\mathbf{U} = C_V dT$ Apply $C_V = (3/2)R$ (given) integrate to $\Delta\mathbf{U} = \int C_V dT = (3/2)R [T_f - T_i]$ $\Delta\mathbf{U} = q + \mathbf{w}$ First Law Rearrange and apply $\mathbf{w} = 0$ $q = \Delta\mathbf{U} - 0$
Step 2	$d\mathbf{U} = C_V dT + (\partial\mathbf{U}/\partial V)_T dV$ Apply $dT = 0$ (constant temperature) Apply $(\partial\mathbf{U}/\partial V)_T = 0$ (ideal gas) $\therefore \Delta\mathbf{U} = 0 + 0$ $d\mathbf{w} = -p_{op}dV$ definition Apply $p_{op} = p_{gas}$ (reversible process) $p_{gas} = nRT/V$ (ideal gas) $\therefore \mathbf{w} = - \int p_{gas} dV = - \int nRT/V dV = -nRT \ln(V_f/V_i)$ $\Delta\mathbf{U} = q + \mathbf{w}$ First Law Rearrange and apply $\Delta\mathbf{U} = 0$ and $\mathbf{w} = -nRT \ln(V_f/V_i)$ from above, $\therefore q = +nRT \ln(V_f/V_i)$

Answers	Work, joules	Heat, joules
Step 1	0 J	$(3/2)(8.3144)(273-172) = 1260$ J
Step 2	$-8.3144(273) \ln(1/2) = +1573$ J	$8.3144(273) \ln(1/2) = -1573$ J

POSSIBLY USEFUL INFO: $1 \text{ J} = 1 \text{ kg m}^2 \text{ s}^{-2}$ $(p + n^2 a/V^2)(V - nb) = nRT$
 $R = 8.31441 \text{ J mol}^{-1} \text{ K}^{-1} = 1.98718 \text{ cal mol}^{-1} \text{ K}^{-1} = 0.082057 \text{ L atm mol}^{-1} \text{ K}^{-1}$ $1 \text{ atm} = 101325 \text{ Pa}$
 $(\partial\mathbf{U}/\partial V)_T = T(\partial p/\partial T)_V - p$ $(\partial\mathbf{H}/\partial p)_T = -T(\partial V/\partial T)_p + V$ $\mu_{JT} \equiv (\partial T/\partial p)_H$ $(\partial\mathbf{H}/\partial p)_T = -C_p \mu_{JT}$
 $C_p - C_V = \{p + (\partial\mathbf{U}/\partial V)_T\}(\partial V/\partial T)_p$
 special case : $[T_f/T_i]^{C_V/R} = [V_i/V_f]$ only for ideal gas undergoing reversible adiabatic process

1. Two moles of a van der Waals gas undergoes isothermal expansion from 1 atm, 200 K to ten times its initial volume against a constant pressure of 0.1 atm. The parameters for this gas are:
 $a = 1.4 \text{ L}^2 \text{ atm mol}^{-2}$, $b = 0.39 \text{ L mol}^{-1}$,
 $C_V = (5/2)R - 0.370 \times 10^{-3}T + 25.46 \times 10^{-7}T^2 \text{ cal mol}^{-1} \text{ K}^{-1}$.
 Find the initial volume in liters, final pressure in atm, w , q , ΔU , ΔH in J

Space for a sketch (if desired)

Solutions	
initial volume	
final pressure	
w	
q	

ΔU	
ΔH	

	Answers	Final number	Units
initial volume			L
final pressure			atm
w			J
q			J
ΔU			J
ΔH			J

2. The compressibility factor for a gas at 20° C is described by this equation for pressures up to 10 atm:

$Z = 1 - 2.024 \times 10^{-2} p$. The following properties of this gas are also known:

$$C_V = 2.97 + 10.5 \times 10^{-3} T \text{ cal K}^{-1} \text{ mol}^{-1}$$

$$C_p = 5.65 + 11.44 \times 10^{-3} T \text{ cal K}^{-1} \text{ mol}^{-1}$$

$$(\partial U / \partial V)_T = 2 \times 10^{-3} \text{ cal L}^{-1}$$

Two moles of a gas is compressed adiabatically in a single stage with a constant opposing pressure equal to 10 atm. Initially the gas is at 20° C and 1 atm pressure. The final pressure is 10 atm. Find the initial volume, final volume in liters, final temperature, w , q , ΔU , ΔH in J

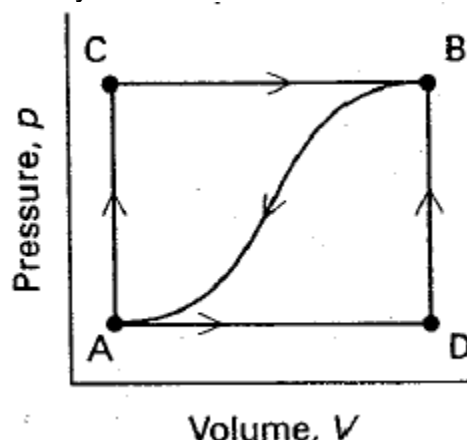
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Solutions	
initial volume	
final volume	
final temperature	

w	
q	
ΔU	
ΔH	

	Answers	Final number	Units
initial volume			L
final volume			
final temperature			
w			
q			
ΔU			
ΔH			

3. When a system is taken from state A to state B along the path A→C→B in the figure below, 80 J of heat flows into the system and the system does 30 J of work.



- (a) How much heat flows into the system along the path A→D→B if the work done is 10 J?
 (b) When the system is returned from state B to A along the curved path, the work done on the system is 20 J. Does the system absorb or liberate heat, and how much?
 (c) If $U_D - U_A = +40$ J, find the heat absorbed in each of the processes A→D and D→B

	Solution	Numerical Answer, J
(a)		$q_{A \rightarrow D \rightarrow B} =$
(b)		$q_{B \rightarrow A} =$
(c)		$q_{A \rightarrow D} =$ $q_{D \rightarrow B} =$

4. A cylindrical container of fixed total volume is divided into three sections, S_1 , S_2 , and S_3 . The sections S_1 and S_2 are separated by an adiabatic piston, whereas S_2 and S_3 are separated by a diathermic (heat conducting) piston. The pistons can slide along the walls of the cylinder without friction. Each section of the cylinder contains 1.00 mole of a perfect diatomic gas [$C_V = (5/2)R$]. Initially the gas pressure in all three sections is 1.00 atm and the temperature is 298 K. The gas in S_1 is heated slowly until the temperature of the gas in S_3 reaches 348 K. Find the final temperature, pressure, and volume, as well as the change in internal energy for each section. Determine the total energy supplied to the gas in S_1 .

Space for a sketch (required)

Solution:

Final Numerical Answers		
Section S ₁	Section S ₂	Section S ₃
$p_{f1} =$ atm	$p_{f2} =$ atm	$p_{f3} =$ atm
$V_{f1} =$ L	$V_{f2} =$ L	$V_{f3} =$ L
$T_{f1} =$ K	$T_{f2} =$ K	$T_{f3} =$ K
$\Delta U_1 =$ cal	$\Delta U_2 =$ cal	$\Delta U_3 =$ cal
Total energy supplied to the gas in Section S ₁ = cal		

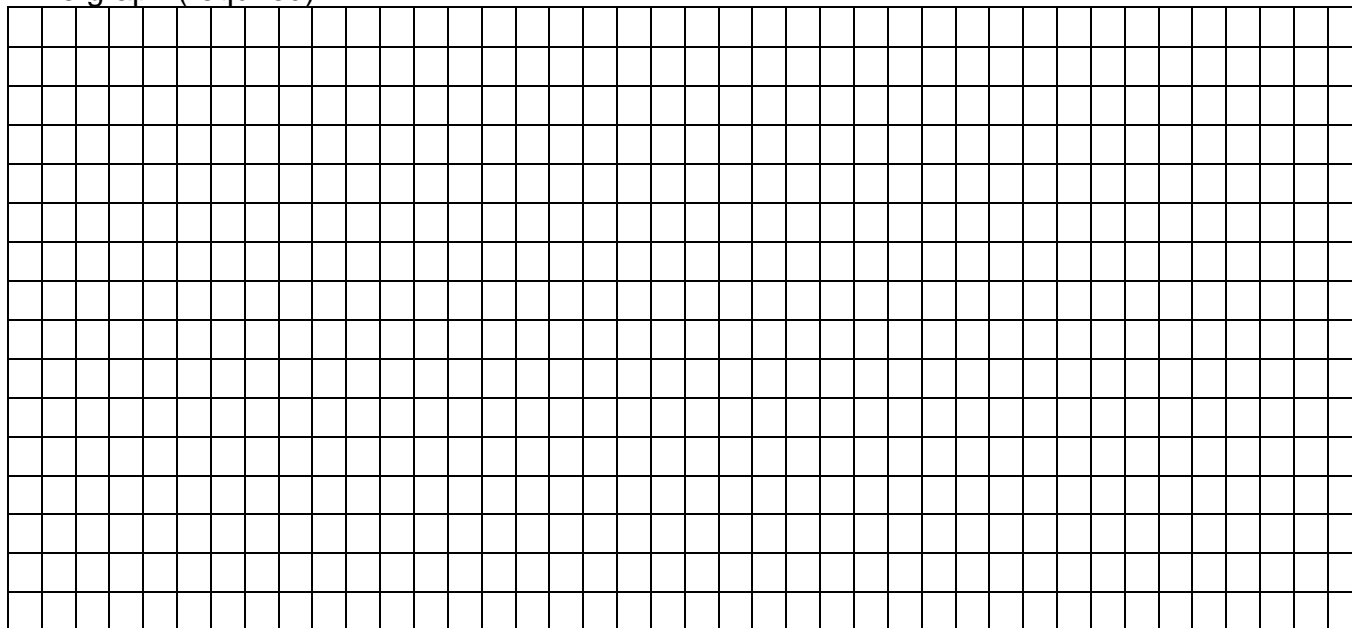
5.(a) The following data have been obtained for the density of a gas as a function of pressure at 10° C. find the molar mass (molecular weight) of the gas.

p, atm	0.68	2.72	8.14
ρ , g L ⁻¹	1.29	5.25	16.31

Hint: the gas is not ideal but you can find the limit of ρ/p as the gas approaches ideality.

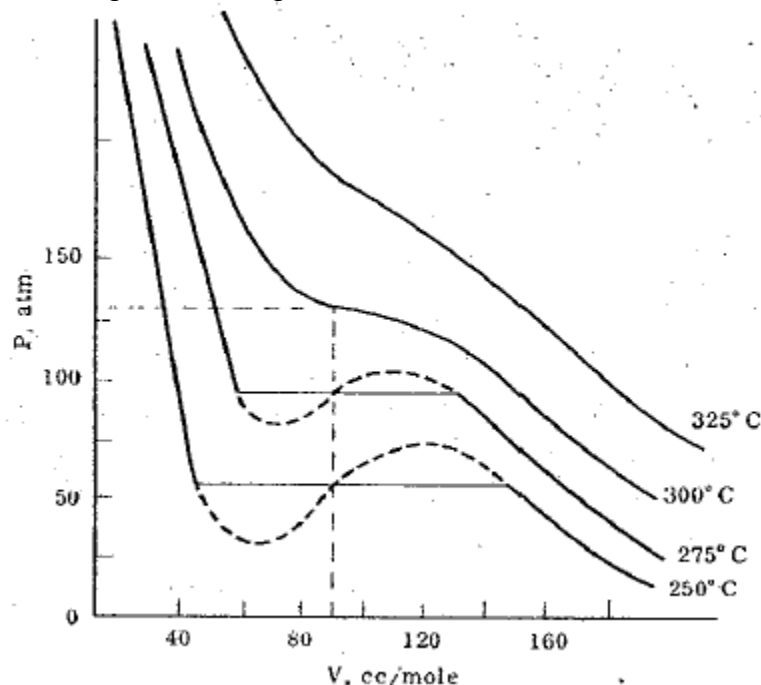
p, atm	0.68	2.72	8.14
ρ/p , g L ⁻¹ atm ⁻¹			

The graph (required):



Solution	Answer	Final number	Units
			g mol ⁻¹

5.(b) Given the pV plots for a gas in the figure below:



	Numerical Answer	$^{\circ}\text{C}$
(a) What is the critical temperature of the gas?		$^{\circ}\text{C}$
(b) What is the critical pressure of the gas?		atm
(c) A sample of the gas is collected in a flask at 325 $^{\circ}\text{C}$. As it is slowly cooled, it condenses at 250 $^{\circ}\text{C}$. What is the density of the sample?		mol L^{-1}
(d) What is the vapor pressure in equilibrium with the liquid at 275 $^{\circ}\text{C}$?		atm

(c) The critical temperature and pressure for several gases are shown below:

gas	T_c, K	p_c, atm
A	300	50
B	600	40
C	280	10
D	20	5

Consult the figure on the next page and answer these questions based on it

	Solution and Reasoning	Answer choose one
(a) Which gas is most nearly ideal in behavior at 300 K and 10 atm?		A B C D
(b) Which is the least ideal		A B C D

