NAME:____
(please print)

CHEMISTRY 230 — Tellinghuisen
1st Hour Exam — 10/4/01

Honor Code Pledge and Signature:

Fundamental Constants: R = 8.31451 J mol^{-1} K^{-1} = 0.0820578 L atm mol^{-1} K^{-1} = 1.9872 cal mol^{-1} K^{-1}

I. (30) **Hot Metal.** 175.0 g of a metal at 115.0˚C is dropped into 24.0 g of water at 10.0˚C, and the system is allowed to reach thermal equilibrium in an open, adiabatic container. The final temperature is 29.0˚C. The heat capacity of water may be taken as c_P = 1.00 cal g^{-1} K^{-1}.

A. Calculate q_{met}, q_{wat}, and the total q for this process. Also determine the average $C_{P,\text{met}}$ and $c_{P,\text{met}}$ over the relevant T range.

B. Assuming that volume changes are negligible, calculate ΔH, ΔU, ΔS_{met}, ΔS_{wat}, and the total ΔS for this process. (Assume heat capacities are constant over the respective T ranges.)

C. Is this process a reversible one?

II. (25) **Heat Pumps, in Hot Times and Cold.** An ideal heat pump (*i.e.*, one operating on a reversible Carnot cycle) is used to maintain a home at 20˚C in winter and at 24˚C in summer. Calculate the pump's ideal efficiency (defined in terms of heat removed or delivered, as appropriate) if the outside temperature is 0˚C in the winter and 35˚C in the summer. Specifically, calculate the ideal amount of heat delivered or removed (as appropriate) in the two seasons (in kJ) per kJ of work input.

III. (25) **Taking Gas (ideally speaking).** n moles of a perfect gas having $C_{V,\mathrm{m}} = \frac{3}{2}R$ is heated from T_1 to T_2 along a path described by $V = bT^3$, where b is a positive constant, independent of T. At all times $P_{\mathrm{ext}} = P$. Obtain expressions for the following: q, w, ΔU, ΔH, and ΔS. [For full credit, your answers should be expressed entirely in terms of n, R, b, T_1, and T_2.]

IV. (40) **The Essentials.**

A. **Plus and Minus.** For each of the following processes, state whether each of the given quantities is positive (+), negative (–), zero, or indeterminate (ind).

1. A perfect gas undergoes a Joule expansion.
2. A real gas undergoes a Joule-Thomson expansion.
3. One mole of liquid water is vaporized reversibly at its normal boiling point.
4. A real gas is taken completely around a Carnot (reversible) cycle in a clockwise sense on a *P-V* diagram.
5. A real gas undergoes a cyclical process that is in part irreversible.
6. $H_2(g)$ and $O_2(g)$ react explosively to form $H_2O(g)$ in an isolated system (*e.g.*, a bomb calorimeter).

	q	w	ΔT	ΔP	ΔU	ΔH	ΔS	ΔS_{univ}
(1)								
(2)								
(3)								
(4)								
(5)								
(6)				+				

B. **Inten/Extensive.** Indicate whether each of the following quantities is intensive, extensive, or neither:

P:

V:

n/V:

T:

S:

mass:

density:

C_P:

(PV_m):

μ_J:

C. **State functions.** Indicate (yes or no) whether each of the following cyclic integrals must vanish for a closed system with *P-V* work only:

$\oint V^2 dP$:

$\oint \frac{dq}{T}$:

$\oint (SdT + TdS)$:

$\oint (dq + dw)$:

$\oint \frac{dw_{rev}}{V}$:

$\oint C_{P,\text{id.gas}}\, dT$:

Prob I ________

II ________

III ________

IV ________

V ________

V. (15) **Derivations. Do ONLY ONE of the following TWO.**

A. Express the exact differential dU for a closed system in terms of the independent variables T and V and also in terms of dq and dw. Combine these to obtain an expression for dq_{rev} in terms of $C_V\,dT$, $P\,dV$, and $(\partial U/\partial V)_T\,dV$.

B. We will soon be able to show that $(\partial H/\partial P)_T = V - T\,(\partial V/\partial T)_P$.

1. What does this equation yield for $(\partial H/\partial P)_T$ for an ideal gas?

2. What does it yield for $(\partial H/\partial P)_T$ for a gas that obeys the equation of state, $P\,(V{-}nb) = nRT$, where b is a constant (independent of T) specific to the gas?

3. Hence, in the latter case what does it yield for the Joule-Thompson coefficient?