

Chemistry 431  
Practice Final Exam  
Fall 2023  
2 Hours

$$R = 8.3144 \text{ J mol}^{-1} \text{ K}^{-1}$$

$$R = .0821 \text{ L atm mol}^{-1} \text{ K}^{-1}$$

$$R = .08314 \text{ L bar mol}^{-1} \text{ K}^{-1}$$

$$k = 1.381 \times 10^{-23} \text{ J molecule}^{-1} \text{ K}^{-1}$$

$$h = 6.626 \times 10^{-34} \text{ Js}$$

$$N_A = 6.022 \times 10^{23} \text{ molecules mol}^{-1}$$

$$F = 96485 \text{ C mol}^{-1}$$

$$g = 9.8 \text{ m s}^{-2}$$

$$1 \text{ atmosphere} = 1.01 \text{ bar} = 1.01 \times 10^5 \text{ N m}^{-2}$$

$$1 \text{ kg} = 1000. \text{ g}$$

$$1 \text{ L} = 10^3 \text{ cm}^3$$

$$10^2 \text{ cm} = 1 \text{ m}$$

$$\sigma = 4\pi r^2 \quad V = (4/3)\pi r^3$$

$$T = t + 273.15$$

$$1 + x + x^2 + x^3 + \dots = 1/(1 - x) \quad |x| < 1$$

**Each question is worth 33 Points. Writing your correct name on the cover and on all pages with work is worth 2 points.**

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Name:

1. Calculate  $q$ ,  $w$ ,  $\Delta U$ ,  $\Delta H$  and  $\Delta S$  when 3.50 moles of an ideal monatomic gas initially at a temperature of  $T_i = 298$  K and a pressure of  $P_i = 1.00$  bar are taken through the following two-step process: 1) the gas is compressed adiabatically and reversibly until the volume is 0.750 times the initial volume, and 2) the gas expands adiabatically against a constant external pressure of 1.00 bar until equilibrium is reached.

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2. Show that

$$\left(\frac{\partial U}{\partial T}\right)_S = \frac{C_V P}{T(\partial P/\partial T)_V}$$

and evaluate the expression for an ideal monatomic gas.

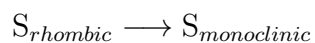
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3. Solid sulfur occurs in two crystalline forms, rhombic and monoclinic. The solubility of rhombic sulfur in  $\text{CCl}_4(\ell)$  is 0.262 molal at 298K. Given  $\Delta_{r,m}G^\ominus$  for the reaction

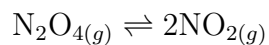


is  $96.1 \text{ J mol}^{-1}$  at 298 K, calculate the molal solubility of monoclinic sulfur in carbon tetrachloride at 298K. You should assume both solutions are sufficiently dilute that the solutes obey Henry's law.

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4. At a total pressure of 4.00 bar, it is found that the degree of dissociation  $\alpha$  for the gas-phase process



is 0.140 at 298K and 0.200 at 308K. Assuming the standard enthalpy change for the reaction is temperature independent, calculate  $\Delta_{r,m}H^\ominus$ ,  $\Delta_{r,m}U$ ,  $\Delta_{r,m}G^\ominus$  and  $\Delta_{r,m}S^\ominus$  for the reaction at 298K.

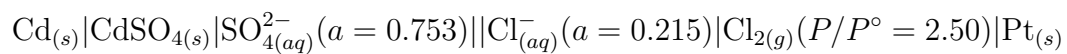
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5. At 298K the EMF of the cell



is 1.652 V. Given the half-cell potentials of the chlorine and cadmium sulfate electrodes to be respectively  $E_{\text{Cl}^{-}/\text{Cl}_2/\text{Pt}}^{\circ} = 1.35827$  V and  $E_{\text{SO}_4^{2-}/\text{CdSO}_4/\text{Cd}}^{\circ} = -0.246$  V, calculate the fugacity coefficient of the chlorine gas in the cell.

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6. The enthalpy of vaporization of rubbing alcohol (liquid isopropan-2-ol,  $\text{CH}_3\text{CHOHCH}_3$ ) is  $\Delta_{\text{vap},m}H = 44.0 \text{ kJ mol}^{-1}$ , and the vapor pressure of rubbing alcohol is  $5.79 \times 10^{-2} \text{ bar}$  at 296 K. A 10.00 L tank fitted with a frictionless piston contains excess liquid rubbing alcohol in equilibrium with its vapor, and the assembly is immersed in a heat bath at a fixed temperature of 308 K. The piston is compressed isothermally against a constant external pressure of 1.00 bar to a final volume of 5.00 L. Calculate  $q$ ,  $w$ ,  $\Delta U$ ,  $\Delta H$ ,  $\Delta S$  and  $\Delta G$  for the compression process.

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# Periodic Table of the Elements

1 <b>H</b> 1.0079 (1A)	2 <b>He</b> 4.0026 (8A)																				
3 <b>Li</b> 6.941 (2A)	4 <b>Be</b> 9.01218 (2A)																				
5 <b>Na</b> 22.9898 (3B)	6 <b>Mg</b> 24.305 (3B)	7 <b>B</b> 10.811 (3A)	8 <b>Al</b> 26.9815 (3A)	9 <b>Si</b> 28.0855 (4A)	10 <b>P</b> 30.9738 (5A)	11 <b>S</b> 32.066 (6A)	12 <b>Cl</b> 35.4527 (7A)	13 <b>Ar</b> 39.948 (8A)													
11 <b>K</b> 39.0983 (4B)	12 <b>Ca</b> 40.078 (4B)	13 <b>Sc</b> 44.9559 (5B)	14 <b>Ti</b> 47.88 (6B)	15 <b>V</b> 50.9415 (6B)	16 <b>Cr</b> 51.9961 (6B)	17 <b>Mn</b> 54.9381 (7B)	18 <b>Fe</b> 55.847 (8B)	19 <b>Co</b> 58.9322 (8B)	20 <b>Ni</b> 58.693 (8B)	21 <b>Cu</b> 63.546 (9B)	22 <b>Zn</b> 65.39 (10B)	23 <b>Ga</b> 69.723 (13A)	24 <b>Ge</b> 72.61 (14A)	25 <b>As</b> 74.9216 (15A)	26 <b>Se</b> 78.96 (16A)	27 <b>Br</b> 79.904 (17A)	28 <b>Kr</b> 83.80 (18A)				
19 <b>Rb</b> 85.4678 (5B)	20 <b>Sr</b> 87.62 (5B)	21 <b>Y</b> 88.9059 (6B)	22 <b>Zr</b> 91.224 (6B)	23 <b>Nb</b> 92.9064 (7B)	24 <b>Mo</b> 95.94 (7B)	25 <b>Tc</b> 98 (7B)	26 <b>Ru</b> 101.07 (8B)	27 <b>Rh</b> 102.906 (8B)	28 <b>Pd</b> 106.42 (8B)	29 <b>Ag</b> 107.868 (9B)	30 <b>Cd</b> 112.411 (10B)	31 <b>In</b> 114.818 (13A)	32 <b>Sn</b> 118.710 (14A)	33 <b>Sb</b> 121.76 (15A)	34 <b>Te</b> 127.60 (16A)	35 <b>I</b> 126.904 (17A)	36 <b>Xe</b> 131.29 (18A)				
27 <b>Cs</b> 132.905 (7A)	28 <b>Ba</b> 137.327 (7A)	29 <b>La</b> 138.906 (8B)	30 <b>Hf</b> 178.49 (8B)	31 <b>Ta</b> 180.948 (9B)	32 <b>W</b> 183.84 (9B)	33 <b>Re</b> 186.207 (9B)	34 <b>Os</b> 190.23 (10B)	35 <b>Ir</b> 192.22 (10B)	36 <b>Pt</b> 195.08 (10B)	37 <b>Au</b> 196.967 (11B)	38 <b>Hg</b> 200.59 (12B)	39 <b>Tl</b> 204.383 (13A)	40 <b>Pb</b> 207.2 (14A)	41 <b>Bi</b> 208.98 (15A)	42 <b>Po</b> 209 (16A)	43 <b>At</b> 210 (17A)	44 <b>Rn</b> 222 (18A)				
35 <b>Fr</b> 223 (7A)	36 <b>Ra</b> 226.025 (7A)	37 <b>Ac</b> 227.028 (8B)	38 <b>Rf</b> 104 (8B)	39 <b>Db</b> 105 (8B)	40 <b>Sg</b> 106 (8B)	41 <b>Bh</b> 107 (9B)	42 <b>Hs</b> 108 (10B)	43 <b>Mt</b> 109 (10B)	44 <b>Ds</b> 110 (10B)	45 <b>Rg</b> 111 (11B)	46 <b>Uub</b> 112 (12B)	47 <b>Uuq</b> 113 (13A)	48 <b>Uuq</b> 114 (14A)	49 <b>Uup</b> 115 (15A)	50 <b>Uuh</b> 116 (16A)	51 <b>Uus</b> 117 (17A)	52 <b>Uuo</b> 118 (18A)				
57 <b>Ce</b> 140.115 (2B)	58 <b>Pr</b> 140.908 (2B)	59 <b>Nd</b> 144.24 (2B)	60 <b>Pm</b> 145 (2B)	61 <b>Sm</b> 150.36 (2B)	62 <b>Eu</b> 151.965 (2B)	63 <b>Gd</b> 157.25 (2B)	64 <b>Tb</b> 158.925 (2B)	65 <b>Dy</b> 162.50 (2B)	66 <b>Ho</b> 164.930 (2B)	67 <b>Er</b> 167.26 (2B)	68 <b>Tm</b> 168.934 (2B)	69 <b>Yb</b> 173.04 (2B)	70 <b>Lu</b> 174.967 (2B)	71 <b>Lr</b> 103 (2B)							
71 <b>Th</b> 232.038 (3B)	72 <b>Pa</b> 231.036 (3B)	73 <b>U</b> 238.029 (3B)	74 <b>Np</b> 237.048 (3B)	75 <b>Pu</b> 244 (3B)	76 <b>Am</b> 243 (3B)	77 <b>Cm</b> 247 (3B)	78 <b>Bk</b> 248 (3B)	79 <b>Cf</b> 251 (3B)	80 <b>Es</b> 252 (3B)	81 <b>Fm</b> 257 (3B)	82 <b>Md</b> 288 (3B)	83 <b>No</b> 259 (3B)	84 <b>Lr</b> 260 (3B)								

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