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CHEM 301

Exam 1

Sept. 20, 2011, 7:55-8:55 AM
4 x 6 note card

Name KEY
Last, First

100 points in ***7 questions on 4 pages plus Tables 2.3 and A.5***
For full credit show all work and put correct units on final answers. Note that information that is not needed may be present in some problems.

(12 pts) 1. Consider a revolving space station as an *isolated* system. As with a merry-go-round, a human being must work hard to move to the center and the exertion will cause the temperature of the air to increase.

Tell whether ΔE, ΔH, q, and w are positive, negative, or zero when a person moves from the edge to the center. (The system is the interior of the space station and all that it contains.) Assume that the system pressure is constant. If there is insufficient information to determine any of the quantities, indication which ones and what you would need to know.

Isolated system, Therefore
ΔE, q, and w = 0
P & V also constant so
ΔH = ΔE + Δ(PV) = 0

q 0

w 0

ΔE 0

ΔH 0

(10 pts) 2. (a) Write the balanced *chemical* equation that has ΔH° equal to $\Delta H°_f$ of $NH_3(g)$ at 298 K.

$\frac{1}{2} N_2(g) + 3/2\ H_2(g) \longrightarrow NH_3(g)$

(b) What is the meaning of the superscript °.

all reactants & products are in their standard state.

(14 pts) 3. If possible, find q, w, and ΔE, ΔH, ΔS, and ΔS_{surr} for 2 mols of ***ideal gas*** with molar C_v = 21 $JK^{-1}mol^{-1}$ if during an ***adiabatic*** process the temperature ***increases*** by 30 K? If insufficient information is given to find certain of these quantities, indicate this and tell what information is missing.

$q = 0$ $\quad \Delta E = w = C_V \Delta T$

$\Delta E = (2\,mol)(21\,JK^{-1}mol^{-1})(30\,K)$

$= 1260\,J$

$\Delta H = \Delta E + \Delta(PV)$

$= \Delta E + \Delta nRT$

$= 1260 + 2(8.3145)30$

$= 1260 + 499 =$

$\Delta S_{surr} = -q/T$

$\Delta S = \int dq_{rev}/T$ but no information about reversibility

q 0

w 1260 J

ΔE 1260 J

ΔH 1759 J

ΔS Cannot determine

ΔS_{surr} 0

(26 pts) 4. (a) If 3 moles of an ideal gas is *expanded isothermally* and *reversibly* at 300 K from a volume of 10 L to 20 L, calculate q, w, ΔE, and ΔH.

$w = -nRT \ln \frac{V_2}{V_1}$

$= -3(8.3145)(300) \ln \frac{20}{10}$

$= -5187\,J$

q +5187 J $= q_{rev}$

w −5187 J

ΔE 0

ΔH 0

(b) If the same isothermal expansion (same initial and final states as in part (a) is done with a constant external pressure of 2.0 atm, again calculate q, w, ΔE,ΔH, and also calculate ΔS and ΔS_{surr} .

$w = -P_{ext}\Delta V$

$= 2\,atm\,(20-10)\,L = -20\,L\,atm$

$-20\,L\,atm \times 101.3\,J/L\,atm = -202.6\,J$

$\Delta S = \frac{q_{rev}}{T} = \frac{5187\,J}{300} =$ ← from part (a)

$\Delta S_{surr} = -\frac{q}{T} = \frac{-202.6}{300} =$

q +2026 J

w −2026 J

ΔE 0

ΔH 0

ΔS 17.29 J/K

ΔS_{surr} −6.75 J/K

(c) Is the process in part (b) reversible or irreversible? Very briefly support your answer.

It is irreversible because $P \neq P_{ext}$

(d) Is the process in part (b) allowed by the Second Law of Thermodynamics? Explain your answer.

Yes. $\Delta S + \Delta S_{surr} > 0$

(12 pts) 5. What 3 conditions must be met in order for ΔH = q?

$P = P_{ext}$ = Constant and PV work only

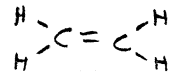
(10 pts) 6. What are the usual standard states for gases, liquids, solids, and solutes?

gas : 1 bar (or 1atm) and ideal

liquid & solid : 1 bar (or 1 atm) and pure

solute : 1 bar (or 1atm), 1 molar, & ideal

(16 pts) 7. Estimate ΔH for the reaction $H_2C{=}CH_2 + 3\ O{=}O \longrightarrow 2H_2O + 2\ O{=}C{=}O$ using the bond enthalpy table provided.

ethylene = 

$$BE(C{=}C) + 4 \times B.E.(C{-}H) + 3 \times BE(O{=}O) - 4\ BE(O{-}H) - 4\ BE(C{=}O)$$

$$= 615 + 4(415) + 3(498) - 4(463) - 4(725)$$

$$= 615 + 1660 + 1494 - 1853 - 2900$$

$$= 3769 - 4752 = \boxed{-983\ kJ\ mol^{-1}}$$

TABLE 2.3 Average Bond Dissociation Energies at 25°C

Bond	D (kJ mol^{-1})
C—C	344
C=C	615
C≡C	812
C—H	415
C—N	292
C—O	350
C=O	725
C—S	259
N—H	391
O—O	143
O—H	463
S—H	339
H_2	436.0
N_2	945.4
O_2	498.3
C (graphite)	716.7

TABLE 2.2 Inorganic Compounds

	$\Delta H_f^\circ \equiv \bar{H}^\circ$ (kJ mol^{-1})	$\bar{S}^\circ$ (J K^{-1} mol^{-1})
Ag(s)	0	42.55
$Ag^+(aq)^\dagger$	105.579	72.68
AgCl(s)	−127.068	96.2
C(g)	716.682	158.096
C(s, graphite)	0	5.740
C(s, diamond)	1.895	2.377
Ca(s)	0	41.42
$CaCO_3$(s, calcite)	−1206.92	92.9
$Cl_2(g)$	0	223.066
$Cl^-(aq)$	−167.159	56.5
CO(g)	−110.525	197.674
$CO_2(g)$	−393.509	213.74
$CO_2(aq)$	−413.80	117.6
$HCO_3^-(aq)$	−691.99	91.2
$CO_3^{2-}(aq)$	−677.14	−56.9
Fe(s)	0	27.28
$Fe_2O_3(s)$	−824.2	87.40
$H_2(g)$	0	130.684
$H_2O(g)$	−241.818	188.825
$H_2O(l)$	−285.830	69.91
$H^+(aq)$	0	0
$OH^-(aq)$	−229.994	−10.75
$H_2O_2(aq)$	−191.17	143.9
$H_2S(g)$	−20.63	205.79
$N_2(g)$	0	191.61
$NH_3(g)$	−46.11	192.45
$NH_3(aq)$	−80.29	111.3
$NH_4^+(aq)$	−132.51	113.4
NO(g)	90.25	210.761
$NO_2(g)$	33.18	240.06
$NO_3^-(aq)$	−205.0	146.4
$Na^+(aq)$	−240.12	59.0
NaCl(s)	−411.153	72.13
NaCl(aq)	−407.27	115.5
NaOH(s)	−425.609	64.455
$O_2(g)$	0	205.138
$O_3(g)$	142.7	238.93
S(rhombic)	0	31.80
$SO_2(g)$	−296.830	248.22
$SO_3(g)$	−395.72	256.76