

1 point each. 28 points in total for Multiple Choice.

For each question enter the one correct answer on the TEST SCORING SHEET in pencil. The TEST SCORING SHEET will be considered final no matter what you marked on the examination paper.

1. Given $2 \text{ C}_2\text{H}_6(g) \rightarrow 2 \text{ C}_2\text{H}_4(g) + 2 \text{ H}_2(g) \quad \Delta H = -64.2 \text{ kJ}$
 ΔH for the reaction of 6.000 g of $\text{C}_2\text{H}_6(g)$ to give $\text{C}_2\text{H}_4(g)$ and $\text{H}_2(g)$ is:

$$\Delta H = \frac{-64.2}{2} \left(\frac{6}{A} \right) = -6.41 \text{ kJ}$$

- A) 6.41 kJ **B) -6.41 kJ** C) -64.2 kJ D) -12.8 kJ E) -25.6 kJ
2. Which of the following statements is true for the combustion of propane, $\text{C}_3\text{H}_8(g)$, to produce carbon dioxide and water vapor in a bomb calorimeter ?

- A)** $\Delta U = 0$
B) $q = \Delta U$
C) $w = \Delta U$
D) $q = 0$
E) $\Delta H = \Delta U$

3. A calorimeter containing 200 mL of water was calibrated by carrying out a reaction which absorbed 15.6 kJ of heat. The temperature of the calorimeter and contents fell 3.25°C . The heat capacity of this calorimeter and contents was:

$$\Delta H_{\text{cal}} = -15.6 \text{ kJ}$$

$$q = c \Delta t$$

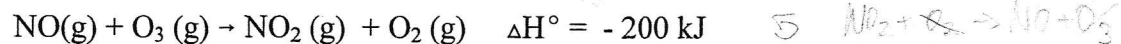
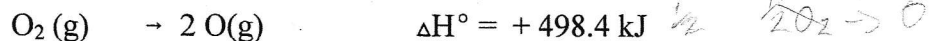
$$c = \frac{q}{\Delta t}$$

- A) $-4.80 \text{ kJ}/^\circ\text{C}$ B) $4.80 \text{ kJ mL}/^\circ\text{C}$ C) $15.6 \text{ kJ}/^\circ\text{C}$ D) $9.60 \text{ kJ}/^\circ\text{C}$
E) $4.80 \text{ kJ}/^\circ\text{C}$

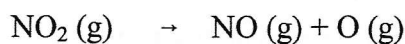
4. The standard enthalpy of sublimation of bromine is $40.1 \text{ kJ}\cdot\text{mol}^{-1}$ and the standard enthalpy of fusion of bromine is $10.6 \text{ kJ}\cdot\text{mol}^{-1}$. The enthalpy of vaporization of liquid bromine is:

- A) $-50.7 \text{ kJ}\cdot\text{mol}^{-1}$ B) $+50.7 \text{ kJ}\cdot\text{mol}^{-1}$ **C) $+29.5 \text{ kJ}\cdot\text{mol}^{-1}$** D) $-29.5 \text{ kJ}\cdot\text{mol}^{-1}$
 E) $-10.6 \text{ kJ}\cdot\text{mol}^{-1}$

5. Given that the standard molar enthalpy of formation of ozone, O_3 , is $+142.7 \text{ kJ/mol}$ and



Calculate the reaction enthalpy for



- A) $+592 \text{ kJ}$ B) $+192 \text{ kJ}$ **C) $+307 \text{ kJ}$** D) $+555 \text{ kJ}$
 E) $+355 \text{ kJ}$

6. The standard enthalpy of formation of KCl(s) is $-437 \text{ kJ}\cdot\text{mol}^{-1}$. In a Born-Haber cycle for KCl(s) which changes are exothermic?

- A) the lattice enthalpy and the electron affinity of the chlorine atom
 B) the electron affinity of the chlorine atom and the reverse of the lattice enthalpy of KCl(s)
 C) the formation of Cl(g) from $\text{Cl}_2(\text{g})$
 D) the sum of the sublimation enthalpy of K(s) and the first ionization energy of K(g)
 E) the lattice enthalpy of KCl(s)

7. Which of the following substances has the largest standard molar entropy at 298 K and 1 atm?

- A) Ag B) Au C) Hg D) Pb E) Fe

8. Estimate the standard molar enthalpy of formation of gaseous carbon monoxide, from the following data: (BE = bond energy)

$$\text{BE (O=O)} = 496 \text{ kJ/mol}$$

$$\text{BE (C}\equiv\text{O)} = 1074 \text{ kJ/mol}$$

$$\text{standard molar enthalpy of formation of C(g)} : 717 \text{ kJ/mol}$$



- A) +965 kJ/mol B) -1074 kJ/mol C) -109 kJ/mol D) +139 kJ/mol

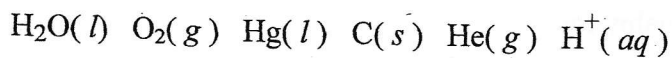
E) -218 kJ/mol

9. Given: $2 \text{ C}_2\text{H}_4(\text{g}) + 6 \text{ O}_2(\text{g}) \rightarrow 4 \text{ CO}_2(\text{g}) + 4 \text{ H}_2\text{O}(\text{g})$

ΔH for this reaction may be estimated from the following bond energies (BE) :

- A) $\Delta H = 8 \text{ BE(C=O)} + 8 \text{ BE(O-H)} - 2 \text{ BE(C=C)} - 8 \text{ BE(C-H)} - 6 \text{ BE(O=O)}$
 B) $\Delta H = 4 \text{ BE(C=O)} + 4 \text{ BE(O-H)} - 2 \text{ BE(C=C)} - 2 \text{ BE(C-H)} - 6 \text{ BE(O=O)}$
 C) $\Delta H = 2 \text{ BE(C=C)} + 8 \text{ BE(C-H)} + 6 \text{ BE(O=O)} - 8 \text{ BE(C=O)} - 8 \text{ BE(O-H)}$
 D) $\Delta H = \text{BE(C=C)} + 4 \text{ BE(C-H)} + 6 \text{ BE(O=O)} - 4 \text{ BE(C=O)} - 4 \text{ BE(O-H)}$
 E) $\Delta H = 2 \text{ BE(C=C)} + 4 \text{ BE(C-H)} - 2 \text{ BE(C=O)} - 3 \text{ BE(O-H)}$

10. Consider the following chemical substances:



Which have standard molar entropies equal to zero at 298 K?

- A) All except $\text{H}_2\text{O}(l)$. B) None. C) $\text{C}(s)$ D) $\text{Hg}(l)$ E) $\text{H}^+(\text{aq})$

- as a reference pt. for other entropies

11. For the reaction: $\text{C}_6\text{H}_6(\text{l}) + 7.5 \text{O}_2(\text{g}) \rightarrow 6 \text{CO}_2(\text{g}) + 3 \text{H}_2\text{O}(\text{g})$

Predict the signs of ΔH and ΔS .

$$\Delta H = -$$

$$\Delta S = +$$

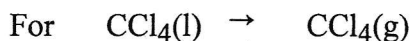
- A) ΔH negative and ΔS positive.
 B) ΔH negative and ΔS negative.
 C) ΔH positive and ΔS positive.
 D) ΔH positive and ΔS negative.
 E) The signs cannot be predicted.

$$\Delta S_{\text{univ}} = \Delta S_{\text{sys}} - \frac{\Delta H}{T}$$

12. Calculate the entropy change of the universe at 298.0 K for a reaction in which the enthalpy change is -296.83 kJ/mol . and the entropy change is $+11.28 \text{ J/K}\cdot\text{mol}$.

- A) $+11.28 \text{ J/K}\cdot\text{mol}$ B) $-11.28 \text{ J/K}\cdot\text{mol}$ C) $+1007.4 \text{ J/K}\cdot\text{mol}$ D) $-1007.4 \text{ J/K}\cdot\text{mol}$
 E) $+984.8 \text{ J/K}\cdot\text{mol}$

13. The vapor pressure of carbon tetrachloride at 20°C is 110 Torr.



ΔG° in kJ/mol at 20°C is

- A) $-(0.0083145)(293)\ln(0.145)$ B) $-(8.3145)(293)\ln(0.145)$
 C) $+(0.0083145)(293)\ln(0.145)$ D) $-(8.3145)(20)\ln(110)$ E) 0

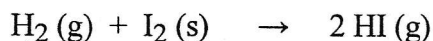
14. The standard molar enthalpy of vaporization of ethanol is $38.7 \text{ kJ}\cdot\text{mol}^{-1}$ at its normal boiling point of 78°C . ΔS° for the vaporization of 1 mole of ethanol at its normal boiling point is:

- A) $103 \text{ J}\cdot\text{K}^{-1}$ B) $292 \text{ J}\cdot\text{K}^{-1}$ C) $496 \text{ J}\cdot\text{K}^{-1}$ D) $110 \text{ J}\cdot\text{K}^{-1}$ E) $142 \text{ J}\cdot\text{K}^{-1}$

$$\Delta S = \frac{\Delta H}{T}$$

15. The standard molar free energy of formation of $\text{HI}(\text{g})$ at 298 K is 1.576 kJ/mol .

At 298 K, calculate the value of the equilibrium constant for the reaction:



$$K = e^{\left(\frac{-2(1.576)}{0.0083145(298)}\right)}$$

$$= 0.280$$

- A) 0.999 B) 0.529 C) 3.570 D) 0.280 E) 1.889

16. Consider a reaction with a negative standard reaction enthalpy and a negative standard reaction entropy. Which of the following statements is true ?

- A) The equilibrium constant K is greater than 1 at low enough temperatures.
 B) The equilibrium constant K is greater than 1 at high enough temperatures.
 C) Reactants are favored at low temperature.
 D) Products are favored at high temperature.
 E) The equilibrium constant K can never be greater than 1.

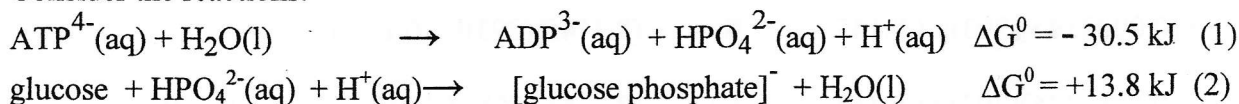
17. Which of the following has the largest molar entropy at 298 K ?

- A) $I_2(s)$ B) $Cl_2(g)$ C) $F_2(g)$ D) $Br_2(g)$ E) $Br_2(l)$

18. If the enthalpy of fusion of water at its normal melting point is 6.00 kJ/mol, ΔS^0 for freezing 1 mole of water at this temperature is:

- A) -20.1 JK^{-1} B) -6.00 kJK^{-1} C) $+6.00 \text{ kJK}^{-1}$ D) -22.0 JK^{-1}
 E) $+22.0 \text{ JK}^{-1}$

19. Consider the reactions:



Coupling these two reactions in biological systems favors formation of the product glucose-6-phosphate because:

- A) Reaction 1 is more exergonic than Reaction 2 is endergonic.
 B) Reaction 2 favors products.
 C) Reaction 1 favors reactants.
 D) The sum of Reaction 1 and Reaction 2 gives a reaction which favors reactants.
 E) None of the above.

20. For the reaction:



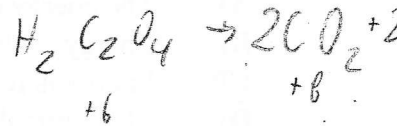
$\Delta H^0 = 92.22 \text{ kJ}$ and $\Delta S^0 = 198 \text{ JK}^{-1}$ at 298 K.

With all reactants and products in their standard states, this reaction will be spontaneous

- A) at no temperatures..
 B) at all temperatures.
 C) at temperatures above 191 C.
 D) at 273 K.
 E) at temperatures below 190 C.

21. When a reaction takes place and the products have a lower energy than the reactants,
- A) The energy of the system increases.
 - B) Energy is absorbed.
 - C) Energy is released.
 - D) The thermal motion of the atoms in the surroundings decreases.
 - E) The reaction is endothermic.
22. When benzene vapor ^{g > l} condenses at constant pressure, the sign of the enthalpy change for the process
- A) depends on the container volume.
 - B) depends on the temperature..
 - C) is positive.
 - D) cannot be determined.
 - E) is negative.
23. If the average O-H bond enthalpy is 463 kJ/mol estimate the enthalpy change when water vapor dissociates to gaseous atoms. $H_2O(g) \rightarrow 2H(g) + O(g)$
- A) 926 kJ/mol
 - B) 1389 kJ/mol
 - C) 463 kJ/mol
 - D) -926 kJ/mol
 - E) -463 kJ/mol
24. Calculate the work needed to make room for products in the combustion of 1 mole of $CH_4(g)$ to carbon dioxide and water vapor. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$
 $\Delta n = 0$
- A) -4.52 kJ
 - B) -2.26 kJ
 - C) -6.79 kJ
 - D) -11.3 kJ
 - E) no work is needed.
25. The standard free energy of formation of $CS_2(l)$ a common solvent is 65.27 kJ/mol at 298K. This means that at 298K
- A) $CS_2(l)$ is thermodynamically unstable.
 - B) $CS_2(l)$ is thermodynamically stable.
 - C) no catalyst can decompose $CS_2(l)$ into its elements.
 - D) $CS_2(l)$ has a negative entropy.
 - E) $CS_2(l)$ will not spontaneously form $C(s)$ and $2S(s)$

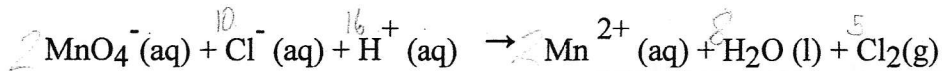
26. Given $\overset{+1 \ +3 \ -2}{\text{H}_2\text{C}_2\text{O}_4}(\text{aq}) \rightarrow \overset{+4 \ -2}{2\text{CO}_2}(\text{g})$ in acidic solution.



The number of electrons in the balanced half-reaction is:

- (A) 2 (B) 3 (C) 5 (D) 10 (E) 1

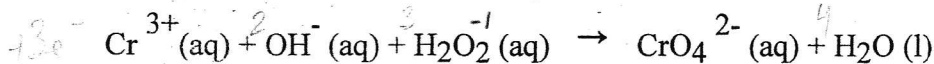
27. Given:



If the coefficient of Cl^- in the balanced equation is 10 then the coefficients of MnO_4^- , H^+ , and Cl_2 respectively are

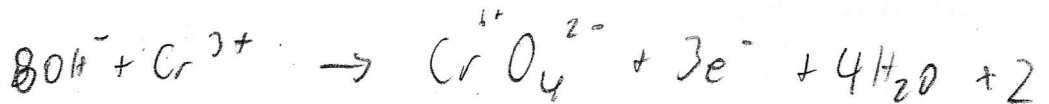
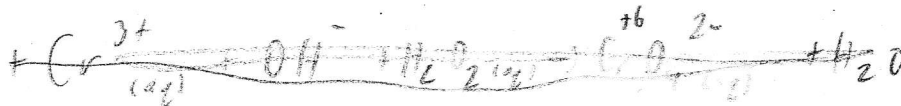
- (A) 2, 10, 5 (B) 8, 16, 5 (C) 2, 16, 5 (D) 1, 16, 5 (E) 5, 8, 5

28. Given the unbalanced reaction:



How many electrons are transferred when the reaction is balanced?

- (A) 6 (B) 12 (C) 3 (D) 2 (E) 8

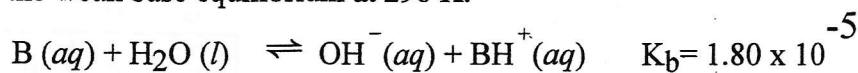


1. [6 points] At the normal boiling point of xenon, Xe, -108.1°C , ΔH° of vaporization is 12.63 kJ/mol . Assume that the volume of 1 mole of liquid xenon is negligible with respect to 1 mole of the gas and that xenon vapor behaves as an ideal gas. Determine the following quantities for a phase transition of 1 mole of xenon liquid to 1 mole of xenon vapor at its normal boiling point.

$w = -\Delta nRT$ $= -1\text{ mol}(8.3145 \times 10^{-3}\text{ kJ/K}\cdot\text{mol})(164.9\text{ K})$ $= -1.371\text{ kJ}$ $q = \Delta H^\circ(n)$ $= 12.63\text{ kJ/mol}(1\text{ mol})$ $= 12.63\text{ kJ}$	$\Delta U^\circ = q + w$ $= 12.63 - 1.371$ $= 11.26\text{ kJ}$
$\Delta S^\circ = \frac{\Delta H^\circ}{T}$ $= \frac{12.63\text{ kJ/mol}(1\text{ mol})}{164.9\text{ K}}$ $= 76.59\text{ J/K}$	ΔG° @ equilibrium $\therefore \Delta G^\circ = 0$ $\Delta G^\circ = \Delta H - T\Delta S$ $= 12.63 - 164.9(0.07659)$ $= 0$

2. [6 points]

Consider the weak base equilibrium at 298 K .



Calculate ΔG when

$$[\text{OH}^-(aq)] = [\text{BH}^+(aq)] = 1.00 \times 10^{-5}\text{ M}$$

$$\text{and } [\text{B}(aq)] = 0.100\text{ M.}$$

$$\begin{aligned} \Delta G_{\text{rxn}} &= RT \ln\left(\frac{Q}{K}\right) \\ &= 8.3145 \times 10^{-3}\text{ J/K}\cdot\text{mol}(298\text{ K}) \ln\left(\frac{1.00 \times 10^{-9}}{1.80 \times 10^{-5}}\right) \\ &= -22.8\text{ kJ/mol} \end{aligned}$$

- calculation error = -24.3 kJ/mol

$$\begin{aligned} Q &= \frac{[\text{BH}^+][\text{OH}^-]}{[\text{B}]} \\ &= \frac{(1.00 \times 10^{-5})^2}{0.100} \\ &= 1.00 \times 10^{-9} \end{aligned}$$

11

Data Page

Nothing written on this page will be graded.

$R = 8.3145 \text{ J/K} \cdot \text{mol}$

$1 \text{ atm} = 101.3 \text{ kPa} = 760.0 \text{ Torr}$

$1 \text{ L} \cdot \text{atm} = 101.3 \text{ J}$

$0 \text{ }^\circ\text{C} = 273.15 \text{ }^\circ\text{K}$

Specific Heat of $\text{H}_2\text{O}(l)$ $4.184 \text{ J/}^\circ\text{C} \cdot \text{g}$

Relative molar masses.

H 1.008

C 12.01

O 16.00

PERIODIC TABLE

1A																	2
1																	2
H																	He
Hydrogen																	Helium
2A												3A	4A	5A	6A	7A	
3	4											5	6	7	8	9	10
Li	Be											B	C	N	O	F	Ne
Lithium	Beryllium											Boron	Carbon	Nitrogen	Oxygen	Fluorine	Neon
11	12											13	14	15	16	17	18
Na	Mg											Al	Si	P	S	Cl	Ar
Sodium	Magnesium											Aluminum	Silicon	Phosphorus	Sulfur	Chlorine	Argon
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Potassium	Calcium	Scandium	Titanium	Vanadium	Chromium	Manganese	Iron	Cobalt	Nickel	Copper	Zinc	Gallium	Germanium	Arsenic	Selenium	Bromine	Krypton
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Rubidium	Strontium	Yttrium	Zirconium	Niobium	Molybdenum	Technetium	Ruthenium	Rhodium	Palladium	Silver	Cadmium	Indium	Tin	Antimony	Tellurium	Iodine	Xenon
55	56	57-71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs	Ba	Lanthanides	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Cesium	Barium		Hafnium	Tantalum	Tungsten	Rhenium	Osmium	Iridium	Platinum	Gold	Mercury	Thallium	Lead	Bismuth	Polonium	Astatine	Radon
87	88	89-103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
Fr	Ra	Actinides	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub	Uut	Uuq	Uup	Uuh	Uus	Uuo
Francium	Radium		Rutherfordium	Dubnium	Seaborgium	Bohrium	Hassium	Meitnerium	Darmstadtium	Roentgenium	Ununbium	Ununtrium	Ununquadium	Ununpentium	Ununhexium	Ununseptium	Ununoctium