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 $2\ C_2H_6\ (g) \rightarrow 2\ C_2H_4\ (g) + 2\ H_2\ (g)$ $\Delta H = -64.2$ kJ

ΔH for the reaction of 6.000 g of $C_2H_6\ (g)$ to give $C_2H_4\ (g)$ and $H_2\ (g)$ is:

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, $C_3H_8(g)$, 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:

A) - 4.80 kJ /°C **B)** 4.80 kJ mL /°C **C)** 15.6 kJ/°C **D)** 9.60 kJ/°C
E) 4.80 kJ /°C

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

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

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

$$O_2\ (g) \rightarrow 2\ O(g) \qquad \Delta H° = +498.4 \text{ kJ}$$

$$NO(g) + O_3\ (g) \rightarrow NO_2\ (g) + O_2\ (g) \qquad \Delta H° = -200 \text{ kJ}$$

Calculate the reaction enthalpy for

$$NO_2\ (g) \rightarrow NO\ (g) + O\ (g)$$

A) +592 kJ **B)** + 192 kJ **C)** + 307 kJ **D)** +555 kJ
E) + 355 kJ

6. The standard enthalpy of formation of KCl(s) is -437 kJ·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 $Cl_2(g)$
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)

BE (O=O) = 496 kJ/mol
BE (C≡O) = 1074 kJ/mol
standard molar enthalpy of formation of C(g) : 717 kJ/mol

A) + 965 kJ/mol B) - 1074 kJ/mol C) - 109 kJ/mol D) + 139 kJ/mol
E) -218 kJ/mol

9. Given: $2\ C_2H_4(g) + 6\ O_2(g) \rightarrow 4\ CO_2(g) + 4\ H_2O(g)$

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

A) ΔH = 8 BE(C = O) + 8 BE(O-H) - 2BE(C=C) - 8 BE(C-H) - 6 BE(O = O)
B) ΔH = 4 BE(C = O) + 4 BE(O-H) - 2 BE(C=C) - 2 BE(C-H) - 6 BE(O = O)
C) ΔH = 2 BE(C=C) + 8 BE(C-H) + 6 BE(O = O) - 8 BE(C=O) - 8 BE(O-H)
D) ΔH = BE(C=C) + 4 BE(C-H) + 6 BE(O=O) - 4 BE(C=O) - 4 BE(O-H)
E) ΔH = 2 BE(C=C) + 4 BE(C-H) - 2 BE(C=O) - 3 BE(O-H)

10. Consider the following chemical substances:

$H_2O(l)$ $O_2(g)$ $Hg(l)$ $C(s)$ $He(g)$ $H^+(aq)$

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

A) All except $H_2O(l)$. B) None. C) $C(s)$ D) $Hg(l)$ E) $H^+(aq)$

11. For the reaction: $C_6H_6(l) + 7.5\ O_2(g) \rightarrow 6\ CO_2(g) + 3\ H_2O(g)$

Predict the signs of ΔH and ΔS.

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.

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 J/K•mol.

A) + 11.28 J/K•mol **B)** -11.28 J/K•mol **C)** +1007.4 J/K•mol **D)** -1007.4 J/K•mol
E) + 984.8 J/K•mol

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

For $CCl_4(l) \rightarrow CCl_4(g)$

$\Delta G°$ 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 $kJ \cdot mol^{-1}$ at its normal boiling point of 78 °C. ΔS^0 for the vaporization of 1 mole of ethanol at its normal boiling point is:

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

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

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

$$H_2(g) + I_2(s) \rightarrow 2\ HI(g)$$

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 kJK^{-1} D) -22.0 JK^{-1}

E) +22.0 JK^{-1}

19. Consider the reactions:

$ATP^{4-}(aq) + H_2O(l) \longrightarrow ADP^{3-}(aq) + HPO_4^{2-}(aq) + H^+(aq)$ $\Delta G^0 = -30.5$ kJ (1)

glucose $+ HPO_4^{2-}(aq) + H^+(aq) \longrightarrow$ [glucose phosphate]$^-$ $+ H_2O(l)$ $\Delta G^0 = +13.8$ kJ (2)

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:

$$2\,NH_3(g) \longrightarrow 3H_2(g) + N_2(g)$$

$\Delta H^0 = 92.22$ kJ and $\Delta S^0 = 198\ JK^{-1}$ at 298 K.
With all reactants and products in their standard states, this reaction will be spaotaneous

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 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.

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 $H_2C_2O_4\,(aq) \rightarrow 2CO_2\,(g)$ 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:

$$MnO_4^-\,(aq) + Cl^-\,(aq) + H^+\,(aq) \rightarrow Mn^{2+}\,(aq) + H_2O\,(l) + Cl_2(g)$$

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:

$$Cr^{3+}\,(aq) + OH^-\,(aq) + H_2O_2^{-1}\,(aq) \rightarrow CrO_4^{2-}\,(aq) + H_2O\,(l)$$

How many electrons are transferred when the reaction is balanced ?

A) 6 **B)** 12 **C)** 3 **D)** 2 **E)** 8

164.9 K

1. [6 points] At the normal boiling point of xenon, Xe, - 108.1 °C, ΔH^o 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 $= -\Delta nRT$ $= -1\,mol(8.3145\times10^{-3}\,kJ/K\cdot mol)(164.9\,K)$ $= -1.371\,kJ$ **q** $= \Delta H^o(n)$ $= 12.63\,kJ/mol\,(1\,mol)$ $= 12.63\,kJ$ ✓ 3	**ΔU^o** $= q + w$ $= 12.63 - 1.371$ $= 11.26\,kJ$ 1
ΔS^o $= \frac{\Delta H^o}{T}$ $= \frac{12.63\,kJ/mol\,(1\,mol)}{164.9\,K}$ $= 76.59\,J/K$ 1	**ΔG^o** @ equilibrium $\therefore \Delta G^o = 0$ $\Delta G^o = \Delta H - T\Delta S$ $= 12.63 - 164.9(0.07659)$ $= 0$ 1

6

2. [6 points]

Consider the weak base equilibrium at 298 K.

$$B\,(aq) + H_2O\,(l) \rightleftharpoons OH^-(aq) + BH^+(aq) \qquad K_b = 1.80 \times 10^{-5}$$

Calculate ΔG when

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

and $[B\,(aq)] = 0.100\ M.$

$\Delta G_{rxn} = RT\ln(Q/K)$

$= 8.3145\times10^{-3}\,J/K\cdot mol\,(298\,K)\ln\left(\frac{1.00\times10^{-9}}{1.80\times10^{-5}}\right)$

$= -22.8\,kJ/mol$

- calculation error $= -24.3\,kJ/mol$

$Q = \frac{[BH^+][OH^-]}{[B]}$ ✓

$= \frac{(1.00\times10^{-5})^2}{0.100}$

$= 1.00\times10^{-9}$

5

11

Data Page

Nothing written on this page will be graded.

$R = 8.3145 \ J / K \bullet mol$

1 atm = 101.3 kPa = 760.0 Torr

$1 \ L \bullet atm = 101.3 \ J$

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

Specific Heat of $H_2O(l)$ 4.184 $J / ^{\circ}C \bullet g$

Relative molar masses.

H 1.008

C 12.01

O 16.00

PERIODIC TABLE

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