Worksheet 14: Practice Exam 3 Answer Key

1. Which of the following must true of an isolated system (a system which does not exchange energy of mass with its surroundings) as a result of the First Law of Thermodynamics?
    1. $\Delta S_{univ} > 0$
    2. *$\Delta E = 0$*
    3. $\Delta G < 0$
    4. $\Delta S = q/T$

2. The enthalpy of a system is a measure of _____ at constant _____.
    1. energy; temperature
    2. heat; volume
    3. energy; pressure
    4. heat; temperature
    5. work; energy
    6. *heat; pressure*
    7. work; temperature

3. You touch a reaction beaker and it feels hot. You observe that if the beaker is heated vigorously, the reaction stops. ΔH for the reaction is _____ and ΔS is _____.
    1. positive; positive
    2. positive; negative
    3. negative; positive
    4. *negative; negative*

4. A reaction is carried out in two different environments: in one, the reaction is carried out in a container with thermally insulating walls that can change in size, and in the other, it is carried out in a container with thermall conducting, but rigid, walls. Which of the following quantities are **different** between the two scenarios?
        A. ΔE
        B. q
        C. ΔH
        D. w
        E. ΔS
    1. *B and D.*
    2. All of these.
    3. B and C.
    4. D and E.
    5. B, C, and D.
    6. B, C, D, and E.

5. Which of these is the best explanation for why $O_2(g)$, $H_2(g)$, and $N_2(g)$ all have a heat of formation equal to zero?
    1. They are all so similar to their atomic forms that the heat of formation is negligible.
    2. The heats of formation for homonuclear gases are measured at equilibrium, where $\Delta H = 0$.
    3. The heat of formation for every element is reported with respect to its homonuclear diatomic gaseous form.
    4. *The heat of formation measures the enthalpy change for the formation of the species from its constituents in their standard states; $O_2(g)$, $H_2(g)$, and $N_2(g)$ are the standard states for these elements.*

6. Heating a beaker of water with a blowtorch does very little to the temperature of the water; heating an iron bar for the same amount of time will make the nail hot enough to burn you. Which has a higher heat capacity, and how can you tell?
    1. The iron – its temperature is much more responsive to the same amount of heat.
    2. The water – it is more resistant to the absorption of heat from the blowtorch.
    3. *The water – it takes much more heat to change its temperature by the same amount as the temperature of the nail.*
    4. The iron – it absorbs much more of the heat applied to it than does the water.

7. A certain reaction of 100 g of reactant takes place in a bomb calorimeter and for 2 L of water (density = 1 g/mL), $\Delta T_{H2O} = 5.3°C$. The heat capacity of water is 4.18 J/g°C; assume the heat absorbed by the calorimeter itself is negligible. Which of the following is correct for the **system**?
    1. $\Delta H = +44.3$ kJ
    2. *$\Delta E = -44.3$ kJ*
    3. $\Delta H = -2.22$ kJ
    4. $\Delta E = +2.22$ kJ
    5. $\Delta E = +44.3$ kJ
    6. $\Delta E = -2.22$ kJ
    7. $\Delta H = -44.3$ kJ
    8. $\Delta H = +2.22$ kJ

8. Given the following heat of formation, calculate ΔH for the following reaction.

$10\ Al(s) + 6\ NH_4ClO_4(s) \rightarrow 4\ Al_2O_3(s) + 2\ AlCl_3(s) + 12\ H_2O(l) + 3\ N_2(g)$

$\Delta H_f^\circ\ (NH_4ClO_4(s)) = -295.31$ kJ/mol
$\Delta H_f^\circ\ (Al_2O_3(s)) = -1675.7$ kJ/mol
$\Delta H_f^\circ\ (AlCl_3(s)) = -704.2$ kJ/mol
$\Delta H_f^\circ\ (H_2O(l)) = -285.83$ kJ/mol

1. -2370.4 kJ/mol
2. +2370.4 kJ/mol
3. -9.77 kJ/mol
4. +9769.3 kJ/mol
5. *-9769.3 kJ/mol*
6. -32.8 kJ/mol

9. Given the following, find ΔH for the reaction below.

$CaCO_3 + 2\ HCl \rightarrow CaCl_2 + H_2CO_3$ ΔH = -81.42 kJ/mol
$H_2CO_3 \rightarrow CO_2 + H_2O$ ΔH = -2.20 kJ/mol
$CaCl_2 + 2\ H_2O \rightarrow Ca(OH)_2 + 2\ HCl$ ΔH = -196.75 kJ/mol

$CaCO_3 + H_2O \rightarrow Ca(OH)_2 + CO_2$

1. *-280.37 kJ/mol*
2. -113.13 kJ/mol
3. -117.53 kJ/mol
4. +280.37 kJ/mol
5. +117.53 kJ/mol
6. +113.13 kJ/mol

10. Based on statistical mechanics, what is the approximate internal energy at 298 K of benzene, C_6H_6?

1. 36.0 kJ/mol
2. 18.0 kJ/mol
3. *44.6 kJ/mol*
4. 89.2 kJ/mol
5. 14.9 kJ/mol

11. Given the bond enthalpy data below, calculate the enthalpy of the following reaction:

$CH_4 + 2\ Cl_2 \rightarrow CHCl_3 + HCl + H_2$

C-H: BE = 348 kJ/mol H-Cl: BE = 431 kJ/mol
C-Cl: BE = 337 kJ/mol H-H: BE = 436 kJ/mol
Cl-Cl: BE = 242 kJ/mol

1. -530 kJ/mol
2. +350 kJ/mol
3. -134 kJ/mol
4. *-350 kJ/mol*
5. +134 kJ/mol
6. +302 kJ/mol

12. Calculate the work for the following reaction at 298 K:

$$2\ C_8H_{18}(l) + 25\ O_2(g) \rightarrow 16\ CO_2(g) + 18\ H_2O\ (g)$$

1. -17.34 kJ/mol
2. *-22.30 kJ/mol*
3. 9.00 kJ/mol
4. -9.00 kJ/mol
5. +22.30 kJ/mol
6. +17.34 kJ/mol

13. At a given temperature, methane (CH_4) has _____ internal energy than/as lithium hydride (LiH) because _____.
    1. more; heavier molecules have more energy for the same velocity.
    2. *more; methane contains more atoms, and thus has more degrees of freedom for movement.*
    3. less; lighter molecules move faster at a given temperature than do heavier ones.
    4. less; lithium hydride is asymmetric, so it has two distinct orientations – methane only has one distinct orientation.
    5. the same amount of; the energy of a molecule is determined by the temperature – all molecules have the same average energy at the same temperature.

14. In a calorimetry experiment performed at constant pressure, you measure a temperature change and calculate $m_{H2O}C_{H2O}\Delta T + C_{cal}\Delta T$. What is this quantity?
    1. ΔE_{surr}
    2. ΔE_{sys}
    3. ΔE_{univ}
    4. *ΔH_{surr}*
    5. ΔH_{sys}
    6. ΔH_{univ}

15. 1 g of water boils at constant pressure. ΔH_{vap} for water is 40.7 kJ/mol. Assume the process takes place at the boiling point of water. What is the change in internal energy for this process?
    1. *+2.09 kJ/mol*
    2. -170.09 kJ/mol
    3. +37.60 kJ/mol
    4. +2.21 kJ/mol
    5. +2.26 kJ/mol

16. Which of the following reactions is likely to have the most favorable entropy change?
    1. H_2 (g) + ½ O_2 (g) → H_2O (g)
    2. *H_2O(l) → H_2O (g)*
    3. C_2H_4 (g) + 3 O_2 (g) → 2 CO_2 (g) + 2 H_2O (g)
    4. 2 CH_4 (g) + 3 Cl_2 (g) → 2 $CHCl_3$ (l) + 3 H_2 (g)

17. The enthalpy of vaporization of acetone is 31.3 kJ/mol, and its boiling point is 56.3 °C. What is the entropy change for the vaporization (boiling) of acetone?
    1. 556 kJ/mol K
    2. 556 J/mol K
    3. 10.5 kJ/mol K
    4. *95.0 J/mol K*
    5. Not enough information.

18. Any liquid freezing is an example of a system in which the entropy decreases. Why doesn't this process violate the Second Law of Thermodynamics?
    1. It does. The Second Law is an approximation and not valid in all cases.
    2. As long as no energy is created or destroyed, the Second Law is not violated.
    3. Unless the process takes place at absolute zero, the Second Law doesn't apply.
    4. This is a physical process, not a chemical one; therefore, the Second Law is irrelevant.
    5. *Heat flowing out of the system causes an increase in the disorder of the surroundings, so the entropy of the universe increases.*
    6. The Second Law applies only to isolated systems – if the liquid was isolated from its surroundings, it would never freeze.
    7. The entropy of the system doesn't actually decrease.

19. Which of the following will have the largest deviation from zero entropy at 0 K?
    1. O_2
    2. CH_4
    3. *NH_3*
    4. SF_6
    5. CO_2
    6. According to the Third Law, all of these have zero entropy at 0 K.

20. Explain why CH_3F has more entropy at 0 K than CH_4.
    1. Heavier molecules have more entropy than lighter ones.
    2. Because F has more electrons than H, it has a higher electronic entropy.
    3. The large electronegativity of F gives CH_3F a permanent dipole, which causes it makes it more likely to align in specific crystal formations.
    4. *The F makes CH3F asymmetrical, so it has four non-identical orientations, whereas all orientations of CH4 are identical.*

21. Rank the following in terms of increasing molar entropy: CH_3Cl, BH2Cl, H_2, SF_5Cl.
    1. $SF_5Cl < CH_3Cl < BH_2Cl < H_2$
    2. $H_2 < CH_3Cl < SF_5Cl < BH_2Cl$
    3. $H_2 < CH_3Cl < BH_2Cl < SF_5Cl$
    4. *$H_2 < BH_2Cl < CH_3Cl < SF_5Cl$*
    5. $BH_2Cl < H_2 < SF_5Cl < CH_3Cl$
    6. $CH_3Cl < BH_2Cl < H_2 < SF_5Cl$

22. Imagine that one carbon in buckminsterfullerene, C_{60}, is replaced by a silicon atom, yielding SiC_{59}. This molecule can then orient in 60 different ways. What is the entropy of one mole of SiC_{59} at T = 0K?
    1. *34.0 J/K*
    2. 5.65×10^{-23} J/K
    3. 27.3 kJ/K
    4. 4.53×10^{-20} J/K

23. Which of the following would you be most worried about decomposing if it was left out on a lab bench?
    1. $NH_4NO_3(s)$ $\Delta G_f° = -183.87$ kJ/mol
    2. HCN(s) $\Delta G_f° = +124.97$ kJ/mol
    3. Na(s) $\Delta G_f° = 0$ kJ/mol
    4. SnO(s) $\Delta G_f° = -256.9$ kJ/mol
    5. *$N_2H_4(l)$* *$\Delta G_f° = +149.34$ kJ/mol*

24. A reaction releases 76.3 kJ of heat to its surroundings at 298 K. What is the entropy change of the surroundings?
    1. +22737 J/mol K
    2. *+256 J/mol K*
    3. -256 J/mol K
    4. 0 J/mol K
    5. +76.3 J/mol K
    6. -76.3 J/mol K

25. For the vaporization of ethanol, $\Delta H_{vap} = 38.56$ kJ/mol and $\Delta S_{vap} = 109.7$ J/mol K. what is the boiling point of ethanol?
    1. 0.352 K
    2. 273.502 K
    3. *351.6 K*
    4. 2.84 K
    5. 2842 K

26. Given the following information, calculate ΔS_{univ} for the combustion of methanol at 400 K.

$$2\ CH_3OH + 3\ O_2 \rightarrow 2\ CO_2 + 4\ H_2O$$

	$\Delta H_f°$ (kJ/mol)	$S_m°$ (J/mol K)
CH_3OH	-238.86	126.8
O_2	0	205.14
CO_2	-393.51	213.74
H_2O	-285.83	69.91

1. +3752 J/mol
2. -1501 kJ/mol K
3. *+3511 J/mol K*
4. -1404 kJ/mol
5. +46.7 kJ/mol
6. +117 kJ/mol K

27. For a certain species, both ΔH_f and ΔS_f are negative. The compound will be more stable:
    1. *at low temperatures.*
    2. at high temperatures.
    3. The compound will never even form.
    4. The stability is independent of the temperature.

28. Imagine there is a reaction that is known to occur at the surface of the sun, but which will not occur at any reasonable temperature in the laboratory. ΔH for this reaction is _____ and ΔS is _____.
    1. negative; negative
    2. negative; positive
    3. positive; negative
    4. *positive; positive*

29. Which of the following is the most stable at 298K?
    1. $H_2O(l)$ $\Delta H_f° = -285.83$ kJ/mol $\Delta S_f° = -163.42$ J/mol K
    2. $CH_4(g)$ $\Delta H_f° = -74.81$ kJ/mol $\Delta S_f° = -80.84$ J/mol K
    3. $NH_3(g)$ $\Delta H_f° = -46.11$ kJ/mol $\Delta S_f° = -99.53$ J/mol K
    4. $SF_6(g)$ $\Delta H_f° = -1209$ kJ/mol $\Delta S_f° = -347.99$ J/mol K
    5. *$BF_3(g)$ $\Delta H_f° = -1137.0$ kJ/mol $\Delta S_f° = -56.04$ J/mol K*

30. Find $\Delta G_r°$ for the following reaction, given the thermodynamic information below.

$$2\ C_4H_{10}(g) + 13\ O_2(g) \rightarrow 8\ CO_2(g) + 10\ H_2O(l)$$

	$\Delta H_f°$ (kJ/mol)	$S_m°$ (J/mol K)
$C_4H_{10}(g)$	-126.15	310.1
$O_2(g)$	0	205.14
$CO_2(g)$	-393.51	213.74
$H_2O(l)$	-285.83	69.91

1. *-5492 kJ/mol*
2. +256021 kJ/mol
3. -6015 kJ/mol
4. +5492 kJ/mol
5. +6015 kJ/mol
6. -5754 kJ/mol