Research Project Survey Questions:
Please be sure that you record these answers on the multiple choice Scantron sheet in fields 1 or 2.

The first two questions will contribute to a research project and are not for credit. Your responses will by stripped of any identifying data before reporting.

Please answer questions 1 and 2 BEFORE attempting any midterm questions. We are looking for your expectations before you attempt the exam.

If you do not wish to participate in the research study, please answer "C" for BOTH questions.

1. If you think your grade on this mid-term will be in the range 0 - 69%, answer this question (question 1) and leave question 2 blank. I expect my grade to be in the range…
   A. 0 - 29%
   B. 30 - 49%
   C. 50 - 59%
   D. 60 - 64%
   E. 65 - 69%

2. If you think your grade on this mid-term will be in the range 70 - 100%, answer this question (question 2) and leave question 1 blank. I expect my grade to be in the range…
   A. 70 - 74%
   B. 75 - 79%
   C. 80 - 84%
   D. 85 - 89%
   E. 90 - 100%

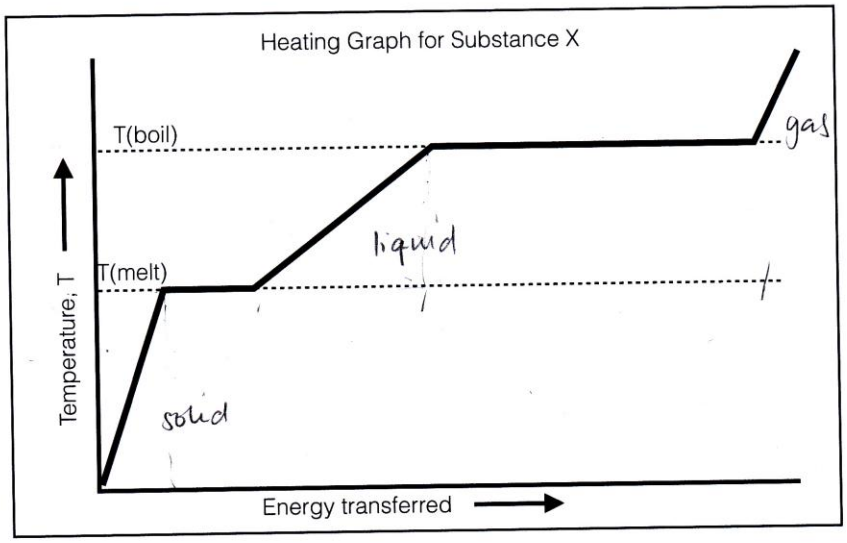
Mid-Term Exam Questions:
Please be sure that you begin recording your exam answers on the Scantron sheet in field 3.

3. The following objects were each heated individually from 25 °C to 37 °C. Which required the most energy?
   A. 15 g of H_2O (C_s = 4.18 J g^{-1} °C^{-1})
   B. 60 g of Al (C_s = 0.902 J g^{-1} °C^{-1})
   C. 20 g of Au (C_s = 0.128 J g^{-1} °C^{-1})
   D. 10 g of Cu (C_s = 0.385 J g^{-1} °C^{-1})
   E. 80 g of CCl_4 (C_s = 0.861 J g^{-1} °C^{-1})

$Q = mC\Delta T$
$= mC(12)$
higher heat capacity requires more energy

4. The molar enthalpy of combustion of sucrose (molar mass is 342 g mol^{-1}) is -5650 kJ mol^{-1}. What mass of sucrose has been burned when 210 kJ of heat is produced by its combustion?
   A. 3.72 g
   B. 9.20 kg
   C. 12.7 g
   D. 9.20 g
   E. 60.5 g

$-5650\,kJ/mol = 210\,kJ / n(mol)$
$= 0.037168\ mol \times 342\ g/mol$
$= 12.71\ g$



5. Based on the heating graph of substance X shown above, which of the phases of X has the largest molar heat capacity?
   A. X(s) solid
   B. solid and liquid are about the same
   C. X(ℓ) liquid
   D. liquid and gas are about the same
   E. X(g) gas

6. Based on the heating graph of substance X shown above, which process required more energy?
   A. Heating the solid to its melting point.
   B. Fusion.
   C. Heating the liquid from its melting point to its boiling point.
   D. Vapourization.
   E. Heating the gas to the final temperature.

7. When ammonia, NH_3, evaporates at constant pressure, the sign of the enthalpy change for the process
   A. is negative.
   B. is positive.
   C. depends on the external pressure.
   D. depends upon the temperature.
   E. cannot be predicted as it can only be measured experimentally.

8. The average bond enthalpy for the O-H bond is 463 kJ mol^{-1}. Estimate the molar enthalpy change when water vapour dissociates into gaseous atoms.
   A. 926 kJ mol^{-1}
   B. 1389 kJ mol^{-1}
   C. 463 kJ mol^{-1}
   D. – 926 kJ mol^{-1}
   E. – 463 kJ mol^{-1}

9. Ozone, $O_3(g)$ is depleted in the atmosphere by reaction with oxygen atoms according to:

$$O_3(g) + O(g) \rightarrow 2\,O_2(g) \quad \Delta H^\circ = -391.87\ kJ\ mol^{-1}$$

The standard molar enthalpy of formation of oxygen atoms is +249.17 kJ mol^{-1}. Calculate the standard molar enthalpy of formation of ozone.

A. -142.70 kJ mol^{-1}
B. +142.70 kJ mol^{-1}
C. -106.47 kJ mol^{-1}
D. +641.04 kJ mol^{-1}
E. -641.04 kJ mol^{-1}

$\frac{1}{2}O_2(g) = O(g)$ $\Delta H = 249.17\ kJ/mol$

$O_3(g) + O(g) \rightarrow 2O_2(g)$ $\Delta H = -391.87\ kJ/mol$) $\times -1$

$\frac{3}{2}O_2(g) = O_3(g)$ $\rightarrow O_3(g) \rightarrow \frac{3}{2}O_2 = 142.1\ kJ/mol$

10. An ideal gas expands isothermally (at constant temperature). In an isothermal process, the internal energy of an ideal gas is unchanged. From the perspective of the system, the heat exchanged in the process is +76 J. What is the energy value for the work?

A. 0 J
B. +76 J
C. –76 J
D. +152 J
E. –152 J

$\Delta U = q + w$

$-w = q$

11. Which of the following statements is true regarding the change in internal energy of a system and its surroundings during an energy exchange in which ΔU_{system} is positive? ← increases

A. The system's internal energy increases and the surrounding's internal energy decreases.
B. The system's internal energy decreases and the surrounding's internal energy increases.
C. The system's internal energy decreases and the surrounding's internal energy is unchanged.
D. The internal energy of both the system and the surroundings decreases.
E. The internal energy of both the system and the surroundings increases.

12. The reaction to form glutamine from glutamate and ammonia is:

Glutamate + NH_3 → Glutamine $\quad \Delta G^\circ = +14.2\ kJ\ mol^{-1}$ (1)

The correct enzyme can couple reaction (1) to the ATP/ADP reaction, i.e.

ATP → ADP + PO_4^{3-}(aq) $\quad \Delta G^\circ = -30.5\ kJ\ mol^{-1}$ (2)

Coupling these two reactions favours the formation of glutamine because:

A. Reaction 1 favours reactants.
B. Reaction 2 favours reactants.
C. Reaction 2 is more exergonic than reaction 1 is endergonic.
D. The sum of reaction 1 and reaction 2 gives a reaction which favours reactants.
E. The sum of reaction 2 and the reverse of reaction 1 gives a reaction with a negative ΔG°.

13. What is the enthalpy of reaction for the process that forms hydrogen cyanide gas, HCN(g)?

$$CH_4(g) + NH_3(g) \rightarrow HCN(g) + 3\,H_2(g)$$

You are given the following thermochemical data:

$\frac{1}{2}N_2(g) + 3\,H_2(g) \rightarrow 2\,NH_3(g) \quad \Delta H^\circ = -91.8\ kJ/mol^{-1}$ $\times -1$

$C(s) + 2\,H_2(g) \rightarrow CH_4(g) \quad \Delta H^\circ = -74.9\ kJ\ mol^{-1}$ $\times -1$

$0.5\,H_2(g) + C(s) + 0.5\,N_2(g) \rightarrow HCN(g) \quad \Delta H^\circ = +135.1\ kJ\ mol^{-1}$

A. -31.6 kJ mol^{-1}
B. +14.3 kJ mol^{-1}
C. +218.5 kJ mol^{-1}
D. +255.9 kJ mol^{-1}
E. +301.8 kJ mol^{-1}

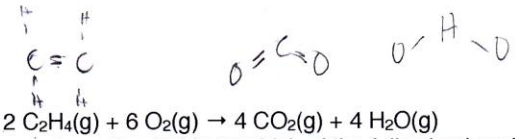
$0.5H_2(g) + C(s) + 0.5N_2 \rightarrow HCN$

$CH_4(g) \rightarrow 2H_2(g) + C(s)$

$NH_3 \rightarrow \frac{3}{2}H_2 + \frac{1}{2}N_2$

$CH_4(g) + NH_3(g) + 3H_2(g) + HCN(g)$

14. Given



$$2\ C_2H_4(g) + 6\ O_2(g) \rightarrow 4\ CO_2(g) + 4\ H_2O(g)$$

ΔH for this reaction can be estimated from which of the following bond energy calculations?

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

15. Of the following reactions, which one will have a positive ΔS° for the reaction?

A. $2\ CO(g) + O_2(g) \rightarrow 2\ CO_2(g)$
B. $2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(g)$
C. $3\ O_2(g) \rightarrow 2\ O_3(g)$
D. $2\ Na(s) + Cl_2(g) \rightarrow 2\ NaCl(s)$
E. $H_2(g) + I_2(s) \rightarrow 2\ HI(g)$

16. Consider the reaction

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

If $\Delta H^\circ = +179\ kJ\ mol^{-1}$ and $\Delta S^\circ = +160\ J\ K^{-1}\ mol^{-1}$ at 298 K, the equilibrium constant will take on a value that is greater than 1 …

A. at no temperature.
B. at all temperatures.
C. at temperatures below 1118 K
D. at temperatures above 2 °C
E. at temperatures above 1120 K

$0 = \Delta H - T\Delta T$

$T = 1118.8\ K$

Greater than 1, more products, spontaneous

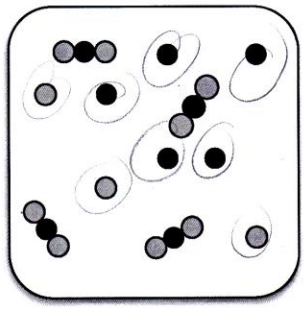
17. A particular process is spontaneous under standard conditions at room temperature, ~~298 K~~. Which set of the following combinations present a reasonable description of the possible changes in entropy, enthalpy, and free energy for this process?

	ΔS° (J/K mol)	ΔH° (kJ/mol)	ΔG° (kJ/mol)
A.	+100	+100	Positive
B.	-100	+50	Negative
C.	+1000	-100	Positive
D.	-100	-100	Negative
E.	-500	-100	Negative

- Cannot be $+H, -S$

If $-H, -S$ spontaneous at low temp

18. In the accompanying molecular scene, the light circles represent a mole of species A while the dark circles represent a mole of species B. The box in which they are contained is considered to be 1 litre. The reaction being depicted is



$$2\ A + B \rightarrow A_2B$$

The standard Gibbs energy ΔG° is +4.5 kJ/mol and the temperature is 298 K. What is ΔG for this reaction under these conditions?

A. +7.8 kJ mol^{-1}
B. +1.2 kJ mol^{-1}
C. +10.5 kJ mol^{-1}
D. +1.5 kJ mol^{-1}
E. –1.5 kJ mol^{-1}

$A_2B = [4]$

$A = [3]^2$

$B = [5]$

$Q = \frac{4}{945}$

$\Delta G = 4.5 + (0.008314)(298)\ln\frac{4}{945}$

$= -1.49$

19. Chloroform, $CHCl_3$, is a liquid whose enthalpy of vaporization at its normal boiling point (61.2 °C) is 29.6 kJ mol^{-1}. What is the entropy change when 1.50 mol of $CHCl_3$ vaporizes at its boiling point?

A. 0.13 J K^{-1}
B. 7255 J K^{-1}
C. 123 J K^{-1}
D. 88.5 J K^{-1}
E. 133 J K^{-1}

$CHCl_3(l) \rightarrow CHCl_3(g)$ $\Delta H = 29.6\ kJ/mol \times 1.50$
$0 = 44.4\ kJ - 334.2\Delta S$ $= 44.4\ kJ$
$\Delta S = 132.85$ $\approx 86\ J/mol$

20. Which expression describes the heat evolved in a chemical reaction that is carried out at constant pressure?

A. q + w
B. ΔU - w
C. ΔH - ΔU
D. ΔU - q
E. ΔU + w

$\Delta U = q + w$
$\Delta U - w = q$

21. The reaction below can be used to produce NO_2 from O_2 and NO.

$$2\ NO(g) + O_2(g) \rightarrow 2\ NO_2(g)$$

At 600 K, the equilibrium constant for this reaction is 250. You set up a reaction condition where all three participants have a concentration of 1.00 x 10^{-3} mol L^{-1} = $[O_2(g)]$ = $[NO(g)]$ = $[NO_2(g)]$. What occurs in the reaction vessel?

A. NO_2 decomposes into O_2 and NO.
B. More NO_2 is produced.
C. Concentrations do not change.
D. NO is consumed by the reaction.
E. System is at equilibrium

$Q = \frac{[NO_2]^2}{[O_2][NO]^2} = 1000$
$Q > K$

22. The Gibbs energy, ΔG, for the reaction A(g) → B(g) is zero under certain conditions. At the same time, ΔG° = 25.0 kJ mol^{-1}. Which statement is true about the reaction?

A. The reaction will proceed in the forward direction to produce more B.
B. The reaction is at equilibrium and [A] > [B].
C. The reaction is at equilibrium and [A] = [B].
D. The reaction is at equilibrium and [A] < [B].
E. The reaction will proceed in the reverse direction to produce more A.

$-RT\ln(K)$ ← K must be negative
∴ more reactants

The following five questions must be answered on the other scantron sheet (not the one with your multiple choice answers).

23. (3 marks) Write down the reaction equation, including phases, for the formation (under standard conditions) of 1 mole of 5-bromouracil ($C_4H_3BrN_2O_2$), as a solid. (This substance can cause mutations in DNA by replacing thymine.)

24. (2 marks) The bond enthalpy for the N≡N bond is 942 kJ mol^{-1}. Write down the chemical reaction equation for the molar enthalpy of formation for gaseous N atoms and give its value in kJ mol^{-1}?

25. (4 marks) Consider two hypothetical elements, X and Y. For both, their standard state is that of a diatomic gas at room temperature. The standard enthalpy of formation of the gas XY is -150 kJ mol^{-1}, while the bond enthalpies of the two elements are BE(X_2) = 300 kJ mol^{-1} and BE(Y_2) = 100 kJ mol^{-1}. Estimate the bond enthalpy of the X-Y bond and report it in kJ mol^{-1}.

26. (10 marks) Consider the reaction $CO(g) + 2\ H_2(g) \rightarrow CH_3OH(\ell)$ and the following data, all measured at 298 K. **Include units in answers.** (The H_2 data is intentionally missing.)

	CO(g)	$CH_3OH(\ell)$
ΔG_f° (kJ mol^{-1})	-137.2	-166.4
ΔH_f° (kJ mol^{-1})	-110.5	-238.7
S° (J K^{-1} mol^{-1})	197.5	126.8

(a) Calculate $\Delta G^\circ_{reaction}$(298 K).
(b) Calculate the equilibrium constant K at 298 K.
(c) Calculate $\Delta H^\circ_{reaction}$(298 K).
(d) Calculate $\Delta S^\circ_{reaction}$(298 K).
(e) Calculate $\Delta G^\circ_{reaction}$ (400 K).

27. (5 marks) The reaction to produce ammonia can be given by the equation

$$N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g).$$

The standard molar free energy of formation of ammonia is -16.45 kJ mol^{-1} at 298K. **Include units in answers.**

(a) Calculate the standard free energy of reaction for the above process at 298 K.

For the following reaction conditions: $P(N_2) = 0.25$ atm; $P(H_2) = 0.75$ atm; $P(NH_3) = 1.50$ atm
(b) Calculate the free energy of reaction for this process at 298 K under these conditions.
(c) Under these conditions, will the reaction proceed in the forward direction, the reverse direction, or is it at equilibrium?

End of Mid-Term Exam Questions
Last two questions are related to the Research Project Survey
Answer these questions back on the Multiple Choice Scantron sheet (not the short answer Scantron).
Use response fields 28 and/or 29.

These last two questions will contribute to a research project and are not for credit. Your responses will be stripped of any identifying data.

Please answer these questions AFTER you complete your midterm.

If you do <u>not</u> wish to participate in the research study, please answer "C" for BOTH questions.

28. If you think your grade on this mid-term will be in the range 0 - 69%, answer this question (question 28) and leave question 29 blank. I expect my grade to be in the range…
A. 0 - 29%
B. 30 - 49%
C. 50 - 59%
D. 60 - 64%
E. 65 - 69%

29. If you think your grade on this mid-term will be in the range 70 - 100%, answer this question (question 29) and leave question 28 blank. I expect my grade to be in the range…
A. 70 - 74%
B. 75 - 79%
C. 80 - 84%
D. 85 - 89%
E. 90 - 100%