Chemistry 1A **Midterm Exam 3** **April 16, 2013**
Professor Pines **(90 minutes, 230 points)** **8 Pages, 30 Questions**

Student Name: KEY Student ID# _____

Potentially Useful Information

Ideal Gas: $PV = nRT$ $N_A = 6.0221 \times 10^{23}$ particles/mol Absolute T(K) = T(°C) + 273.15

$\Delta H_{vap}\ H_2O = 40$ kJ mol^{-1} $C_{H2O} = 4.18\ J/g^oC$ $R = 8.314 \frac{\text{J}}{\text{K mol}} = 0.082 \frac{\text{L atm}}{\text{K mol}}$

$v_{rms} = \sqrt{\overline{v^2}} = \sqrt{\frac{3k_BT}{m}} = \sqrt{\frac{3RT}{m}}$ $x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$

Particle in a 1D box: $E_n = \frac{h^2n^2}{8mL^2}$; $n = 1, 2, 3, \ldots$

$\Delta U = q + w$ $\Delta H = \Delta U + P\Delta V$ $\Delta G° = \Delta H° - T\Delta S°$

$w = -P_{ext}\Delta V$ $S = k_B \ln W$ $\Delta S = \frac{\Delta H}{T_{BP}}$ $k_B = 1.381 \times 10^{-23} \frac{\text{J}}{\text{K}}$

$\Delta H° = \sum \Delta H_f°(products) - \sum \Delta H_f°(reactants)$ $\Delta G° = \sum \Delta G_f°(products) - \sum \Delta G_f°(reactants)$

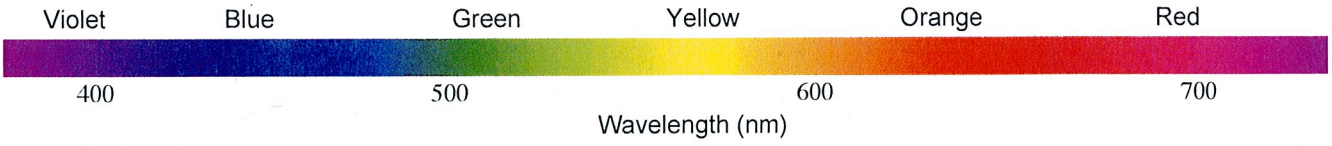
$\Delta S° = \sum \Delta S_f°(products) - \sum \Delta S_f°(reactants)$ $\Delta S = \frac{q_{rev}}{T}$

For reactions of the form $aA + bB \rightarrow cC + dD$, $Q = \frac{[C]^c[D]^d}{[A]^a[B]^b}$. At equilibrium, $Q = K$

$\Delta G° = -RT \ln K$ $\Delta G = \Delta G° + RT \ln Q$ $\ln K = -\frac{\Delta H°}{R}\frac{1}{T} + \frac{\Delta S°}{R}$

$q = mc\Delta T$ $q = mL$ $q_{cal} = -\Delta H_{rxn}$

Average Bond Enthalpies (kJ/mol)					
H – H	436	C – C	348	C – O	360
C = O	192	C = C	612	O – H	463
O – O	146	C ≡ C	838	H – Cl	431
O = O	497	C – H	413	C – Cl	327



$\lambda\nu = c$ $E_{photon} = h\nu$ $c = 2.9989 \times 10^8\ m\ s^{-1}$ $h = 6.62608 \times 10^{-34}\ J\ s$ $p = mv$ $E_k = \frac{mv^2}{2} = \frac{p^2}{2m}$

Only scientific calculators may be used on this exam; graphing calculators (or any calculator with a "Solve" function the capability to store ASCII/text data, etc.) are strictly prohibited. The use of unauthorized materials is considered cheating, and will result in a grade of zero on the exam. At instructor discretion, students found cheating may also be reported to the UC Berkeley Center for Student Conduct.

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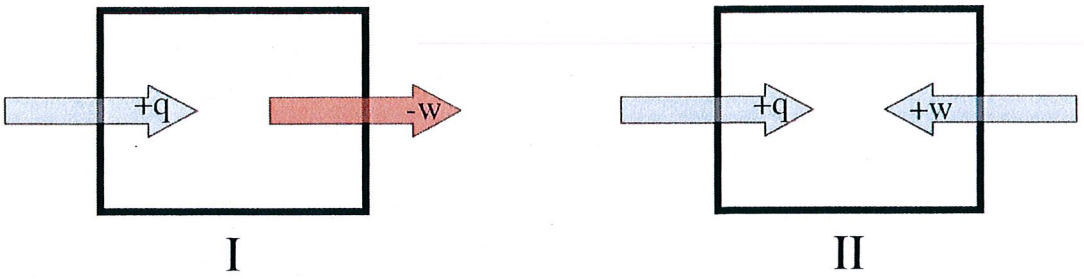
Use the system diagrams below to answer questions 1 and 2:



1. If q = w are both greater than 0, which of these systems experiences an increase in temperature?

A) I B) II C) Both D) Neither E) Not enough information

2. If |q|, |w| > 0, which system represents an adiabatic process?

A) I B) II C) Both D) Neither E) Not enough information

3. The energy difference of an NMR transition is approximately 2×10^{-25} J at 7T. What part of the electromagnetic spectrum does this correspond to?

A) Radio B) IR C) Blue D) UV E) Gamma

4. Which is the best estimate for the boiling point (in °C) of benzene given that ΔH° of vaporization is $31 \frac{\text{kJ}}{\text{mol}}$ and ΔS° of vaporization is $90 \frac{\text{J}}{\text{mol K}}$?

A) 5 B) 15 C) 30 D) 50 E) 70

$\Delta S^\circ = \frac{\Delta H^\circ}{T_{BP}} \rightarrow \frac{\Delta H^\circ}{\Delta S^\circ} = T_{BP} \rightarrow \frac{31000 \text{ J/mol}}{90 \text{ J/mol K}} = T_{BP}$

5. Which is true for the following reaction under standard conditions?

$$C_2H_6(g) \rightarrow C_2H_4(g) + H_2(g) \qquad \Delta H^\circ = 137 \text{ kJ}, \quad \Delta S^\circ = 120 \text{ J/K}$$

A) Spontaneous at all T B) Spontaneous at high T C) Spontaneous at low T

D) Spontaneous at no T E) Cannot be determined

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6. Consider the reaction $N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$ with $\Delta H° = -46.11 \frac{kJ}{mol}$ and $\Delta S° = -198.75 \frac{J}{K\,mol}$. At what temperature is the formation of $NH_3(g)$ spontaneous?

A) 210 K B) 232 K C) 273 K D) All Temperatures E) Never spontaneous

Spontaneous if $\Delta G < 0$ $\Delta G = \Delta H - T\Delta S$

$\Delta H - T\Delta S < 0$

$-46110\ J/mol + T \times -198.75\ J/K\,mol < 0 \rightarrow T < 232\ K$

7. We have seen many times in lecture that heat is given off in the combustion of hydrogen gas. Which of the following is responsible for the heat **released** in the following reaction?

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g) + heat$$

A) Breaking H-H and O-O bonds B) Forming H-H and O-O bonds C) Breaking O-H bonds

D) Forming O-H bonds E) Evaporation of water

8. What is the most dominant intermolecular force in liquid water?

A) Dispersion Forces B) Dipole – Dipole C) Dipole – Induced Dipole

D) Ion – Dipole E) Hydrogen Bonding

9. How much work is done by an adiabatic system with 1 mole of gas and a specific heat of $1.70 \frac{J}{K\,mol}$ if the temperature decreases by 15.0°C?

A) -255 J B) -25.5 J C) 0 J D) 25.5 J E) 255 J

$q = 0 \rightarrow \Delta U = w = mc\Delta T = 1 \cdot 1.7 \cdot -15 = -25.5$ J done on system

or +25.5 J done by system

10. How much energy is ***liberated*** in the following reaction?

$$CH_4(g) + Cl_2(g) \rightarrow CH_3Cl(g) + HCl(g)$$

A) 88 kJ B) 103 kJ C) 167 kJ D) 188 kJ E) 423 kJ

11. A given reaction is endothermic and the change in entropy is negative. The reaction is spontaneous at _____.

A) All T B) No T C) High T only D) Low T only E) 72°F only

positive minus negative is always positive

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12. One mole of carbon atoms reacts to form buckminsterfullerene molecules, C_{60}. How many molecules of C_{60} are formed?

A) 6.0×10^{23} B) 1.0×10^{22} C) 60 D) 1.0 E) 1.7×10^{-2}

$\frac{6 \times 10^{23}}{60} = 1 \times 10^{22}$

13. The value of $\Delta H°$ for the following reaction is -3351 kJ:

$$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$$

How much heat (in kJ) is released by the formation of 75.0 g of $Al_2O_3(s)$?

A) 2.51×10^5 B) 1.26×10^5 C) 2460 D) 1240 E) −3351

101.96 g/mol Al_2O_3

75.0 g → 0.74 mol Al_2O_3 $\left(\frac{3351 \text{ KJ}}{2 \text{ mol } Al_2O_3}\right)$

14. Which of the following has a non-zero ΔH_f°?

A) $O_2(l)$ B) C *(graphite)* C) $N_2(g)$ D) $F_2(g)$ E) $Cl_2(g)$

15. Which of the following processes is endothermic?

A) $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$ B) $H_2O(g) \rightarrow H_2O(l)$ C) $H_2O(s) \rightarrow H_2O(l)$

D) $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$ E) $2Al(s) + Fe_2O_3(s) \rightarrow Al_2O_3(s) + 2Fe(l)$

16. An ideal gas expands isothermally against a vacuum. Which of the following equals zero?

A) w B) q C) ΔT D) All of the above E) None of the above

17. An ideal expands adiabatically against a constant non-zero pressure. Which of the following is negative?

A) w B) q C) ΔT D) All of the above E) None of the above

or

Both allowed

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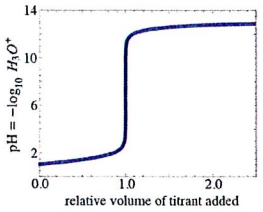
18. Which of the following plots depicts the titration of 1M HNO_3 (strong acid) with 1M NaOH (strong base)?

A



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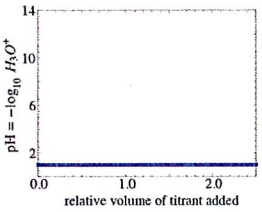

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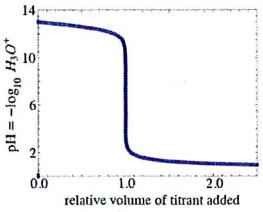

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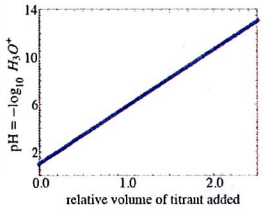
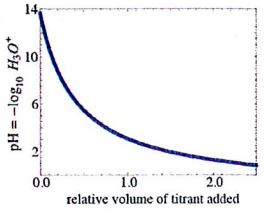


E



19. Consider the hydrogenation/dehydrogenation reactions of acetylene to ethylene, $C_2H_2 + H_2 \leftrightarrow C_2H_4$, and ethylene to ethane, $C_2H_4 + H_2 \leftrightarrow C_2H_6$. Which reaction releases the most heat?

A) Hydrogenation of C_2H_2 B) Hydrogenation of C_2H_4 C) Dehydrogenation of C_2H_6

D) Dehydrogenation of C_2H_4 E) $\Delta H = 0$ for all processes

Either A or B accepted

20. Approximately how much heat (in kJ) is required to convert 100g of liquid water at 90°C to steam at 100°C?

A) 40 B) 100 C) 160 D) 200 E) 230

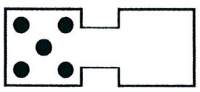
$q_1 = mc\Delta T = (100g)\left(4.18 \frac{J}{g°C}\right)(10°C) = 4.18\ kJ$

$q_2 = n\Delta H_{vap} = \left(\frac{100g}{18\ g/mol}\right)(40\ kJ/mol) = 222\ kJ$

$q_1 + q_2 \approx 226\ kJ$
$\approx 230\ kJ$

21. Which process is accompanied by the greatest increase in entropy?

1



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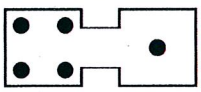

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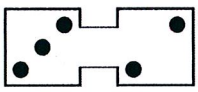

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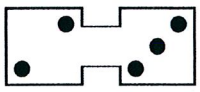

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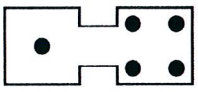
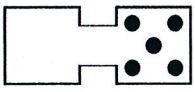


6



A) 1 → 2 B) 2 → 3 C) 1 → 3 D) 2 → 4 E) 5 → 6

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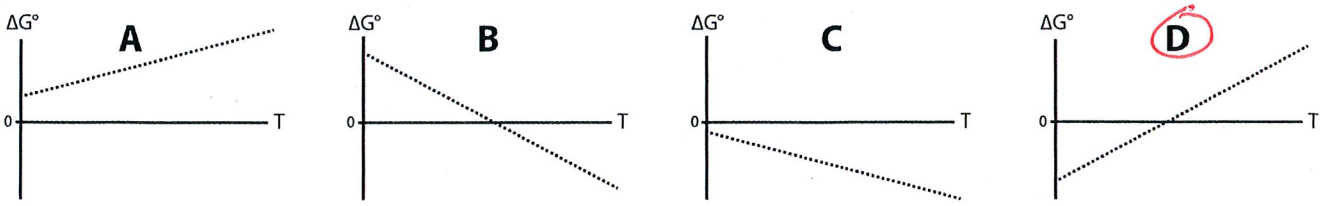
22. At 25°C NO_2 undergoes a dimerization reaction:

$$2NO_2(g) \leftrightarrow N_2O_4(g)$$

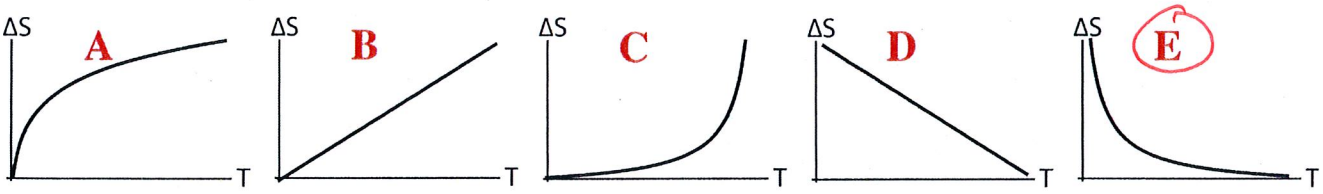
$\Delta S < 0$, and must be negative somewhere

Which of the following could be a plot of ΔG^0 vs. T for this reaction?

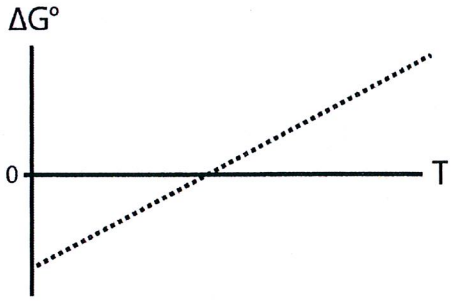


E. None of these

23. Which of the following is a plot of ΔS vs. T for a reversible process (q_{rev} is constant).



24. To which reaction could the following plot of ΔG^0 vs. T correspond?



$\Delta S < 0$

A) $H_2O(l) \leftrightarrow H_2O(g)$ B) $CaCO_3(l) \leftrightarrow CaO(s) + CO_2(g)$ C) $H_2O_2(l) \leftrightarrow H_2O(l) + O_2(g)$

D) $H^+(aq) + Cl^-(aq) \leftrightarrow HCl(aq)$ E) $CO_2(g) \leftrightarrow C(s) + O_2(g)$

D or E accepted

not entropically favored

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25. The gaseous reaction $N_2(g) + 3H_2(g) \leftrightarrow 2NH_2(g)$ at equilibrium, when the volume is suddenly doubled (i.e., the total pressure is halved). Which is true of the reaction quotient Q relative to the equilibrium constant K at the instant that the volume changes?

A) $Q = \frac{1}{4}K$ B) $Q = \frac{1}{2}K$ C) $Q = K$ D) $Q = 2K$ E) $Q = 4K$

$$K = \frac{[NH_3]_{eq}^2}{[N_2]_{eq}[H_2]_{eq}^3}$$

$$Q = \frac{\left(\frac{[NH_3]_{eq}}{2}\right)^2}{\left(\frac{[N_2]}{2}\right)\left(\frac{[H_2]}{2}\right)^3} = 4\frac{[NH_3]_{eq}^2}{[N_2]_{eq}[H_2]_{eq}^3} = 4K$$

26. Which of the following aqueous solutions has the highest pH?

A) 10^{-3}M NaOH B) 10^{-6}M NaOH C) 10^{-3}M HCl D) 10^{-6}M HCl E) 10^{-12}M HCl

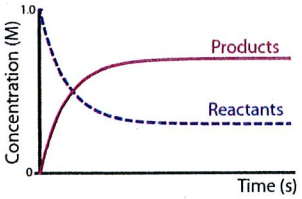
Base pH 11 | Base pH 8 | Acid pH 3 | Acid pH 6 | Acid pH ~7

27. Which of the following plots of product and reactant concentrations vs. time could correspond to a reaction with $K_{eq}<1$?

Reactants $\rightleftharpoons$ Products

$K_{eq} < 1$

A



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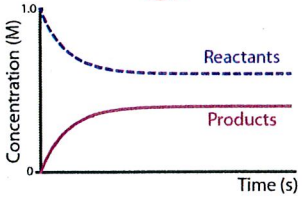

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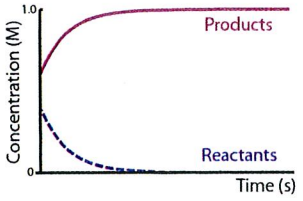
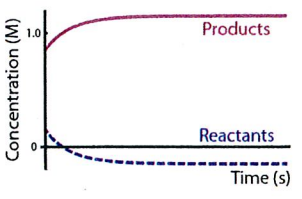


D



E. None of these

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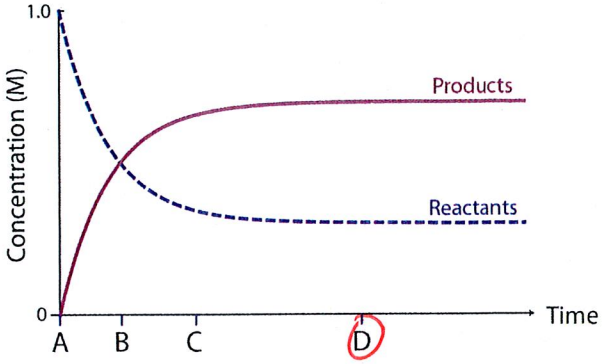
28. At which of the following points can the reaction be considered to be at equilibrium?



E. All of the above

29. Upon dissolution in water, a molecule AB dissociates into molecules of A and B according to

$$AB(aq) \leftrightarrow A(aq) + B(aq)$$

with K_{eq} = 2. What is the equilibrium concentration of molecule A after one mole of AB is added to 1.0 L of water?

A) -2.73 M B) 0.73 M C) 1.0 M D) 1.4 M E) 2.0 M

$K = \frac{[A][B]}{[AB]} = 2 = \frac{x^2}{1-x}$ → $x^2 + 2x - 2 = 0$

	AB	A	B
I	1	0	0
C	1−x	+x	+x
E	1−x	x	x

$x = \frac{-2 \pm \sqrt{2^2 - 4(1)(-2)}}{2}$

$= -1 + \sqrt{3} \approx 0.73\ M$

$-1 - \sqrt{3} = -2.73\ M$ ← not physical

30. The answer to question 30 is A. Please bubble in A for question 30.