Name: Scott Beaver, PhD

[4 pt] 1. How much heat is gained or lost when 1.00 mole of aluminum (Al) reacts in the following equation? Show the correct sign and number of significant figures for ΔH. Indicate whether the reaction is exothermic or endothermic.

$$2\ Al\ (s) + Fe_2O_3\ (s) \rightarrow 2\ Fe\ (s) + Al_2O_3 + 851\ kcal$$

$$(1.00\ mol\ Al)\left(\frac{1\ mol\ rxn}{2\ mol\ Al}\right)\left(\frac{-851\ kcal}{mol\ rxn}\right) = -425.5\ kcal$$

ΔH = -426 kcal

exothermic or endothermic? _____

[6 pt] 2. Use Gibbs Free Energy ΔG to determine if carbon tetrachloride (CCl_4) will spontaneously boil at 373 K. For CCl_4, ΔH_{vap} = +32.54 kJ/mol and ΔS_{vap} = +92.82 J/mol·K. Show a calculation for ΔG.

$$\Delta G = \Delta H - T\Delta S$$

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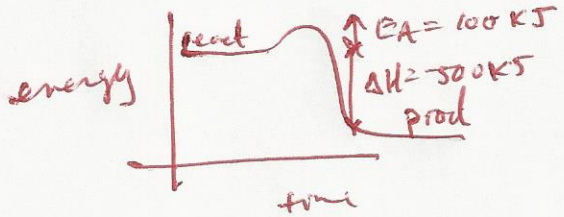
$$= 32.54\ \frac{kJ}{mol} - (373\ K)\left(\frac{0.09282\ kJ}{mol}\right)$$
$$= -2.08\ kJ/mol$$

ΔG = -2.08 kJ/mol

spontaneous at 373K? yes

[4 pt] 3. Draw a reaction diagram (energy vs. time) for an exothermic reaction that releases 500 kJ of energy and has an activation energy of 100 kJ. Label the reactants, products, activation energy, enthalpy change, and both axes.



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[12 pt] 4. Use the Le Chatlier principle to predict the effects on the below equilibrium.

1 mol gas 2 mol gas

Heat + $C(s) + H_2O(g) \rightleftarrows CO(g) + H_2(g)$ $\Delta H = +131$ kcal

a. Does the H_2 level increase, decrease, or stay the same when more carbon (C) is added?

\+ − + + shift →, H_2 ↑

b. What happens to H_2 when more CO is added?

\+ + + − shift ←, H_2 ↓

c. What happens to CO when the total pressure is increased?

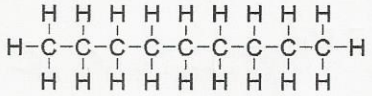
\+ + − − shift ← (less mol gas)
H_2 ↓

d. What happens to CO when the temperature is increased?

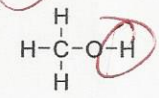
− − + + shift →, endothermic (heat as reactant)

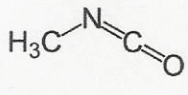
[15 pt] 5. Indicate the strongest intermolecular force (IMF) for the following as pure liquids. Choices are dipole-dipole interactions, London dispersion (van der Waals) forces, and hydrogen bonding.

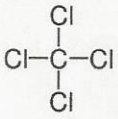
CO ↑

a. nonane (C_9H_{20})  London - hydrocarbon

b. water (H_2O)  H bond

c. methanol (CH_3OH)  H bond

d. methyl isocyante (CH_3NCO)  dipole - polar

e. carbon tetrachloride (CCl_4)  London - nonpolar (symmetrical)

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[3 pt] 6. Rank the following from lowest to highest boiling point: Br_2, Cl_2, I_2, F_2

Same Lewis structure : $\ddot{X}-\ddot{X}:$, biggest/largest surface area has strongest London forces, and highest surface area

b.p. $F_2 < Cl_2 < Br_2 < I_2$ (biggest, highest b.p.)
(smallest, lowest b.p.)

[3 pt] 7. Use the concept of IMFs to explain the low boiling point of O_2, the diatomic oxygen molecule, in 1-3 sentences.

O_2 is symmetric and nonpolar.
Strongest IMF = London forces, which are very weak for this very small molecule.
O_2 molecules do not "stick" strongly as liquid. Low b.p. for this gas.

[2 pt] 8. Convert 3.09 atm to units of mm Hg. Use 760. mm Hg = 1 atm.

$$(3.09\ \text{atm})\left(\frac{760\ \text{mm Hg}}{\text{atm}}\right) = 2348.4\ \text{mm Hg}$$

Pressure = 2350 mm Hg (3 s.f.)

[4 pt] 9. A sample of air has a pressure of 3.9 atm. The oxygen mole percent is 21%. Calculate the partial pressure of oxygen in atm.

$$P_{O_2} = (3.9\ \text{atm})(0.21) = 0.819\ \text{atm}$$

P_{O_2} = 0.82 atm (2 s.f.)

[6 pt] 10. How much energy is gained/released when 20.3 g of water in freezes to form ice given ΔH_{fus} = 333 J/mol? Show the correct sign and number of significant figures.

$$\Delta H = (20.3\ \text{g}\ H_2O)\left(\frac{\text{mol}\ H_2O}{18.01\ \text{g}\ H_2O}\right)\left(-333\ \frac{\text{J}}{\text{mol}\ H_2O}\right)$$

ΔH = −375 J

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[4 pt] 11. The solubility of oxygen in blood 0.44 g/100 mL at sea level where the partial pressure of oxygen is 170 mm Hg. What is the solubility where the partial pressure of oxygen is 25 mm Hg? Apply Henry's Law.

$$0.44 \frac{g}{100mL}\left(\frac{25 \text{ mm Hg}}{170 \text{ mm Hg}}\right) = \boxed{0.065 \frac{g}{100mL}} \quad (2 \text{ s.f.})$$

[6 pt] 12. Use PV = nRT to calculate the number of moles of gas occupying a volume of 12.8 L at a pressure of 994 mm Hg and a temperature of 133 °C. Use R = 0.0821 L·atm/ mol·K.

$$PV = nRT$$

$$n = \frac{PV}{RT} = \frac{(994 \text{ mm Hg})\left(\frac{1 \text{ atm}}{760 \text{ mm Hg}}\right)(12.8 \text{ L})}{\left(0.0821 \frac{\text{L atm}}{\text{mol K}}\right)(406.15 \text{ K})}$$

$$= 0.502 \text{ mol} \quad (3 \text{ s.f.})$$

[6 pt] 13. What is the concentration in units of molarity (M) for 5.18 L of aqueous solution containing 36.8 g of dissolved $MgCl_2$?

$$M = \frac{\text{\# mol}}{L} = \frac{(36.8 \text{ g})\left(\frac{\text{mol}}{95.21 \text{ g}}\right)}{5.18 \text{ L}} = 0.0746 \text{ M} \quad (3 \text{ s.f.})$$

[2 pt] 14. Calculate pH for $[H^+] = 5.5 \times 10^{-4}$ M. Use $pH = -\log([H^+])$ and $[H^+] = 10^{-pH}$.

$$pH = -\log([H^+]) = -\log(5.5 \times 10^{-4}) = -(-3.26) = \boxed{3.26}$$

(2 s.f.; 2 d.p.)

[4 pt] 15. Provide the equilibrium reaction between hydrocyanic acid (HCN) and cyanide ion (CN^-) in water. Label the Lewis acid/base and conjugate base/acid.

$$\underset{\text{acid}}{HCN} + \underset{\text{base}}{H_2O} \rightleftharpoons \underset{\text{conjugate base}}{CN^-} + \underset{\text{conjugate acid}}{H_3O^+}$$

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[4 pt] 16. Find the concentration if 25 mL of a 1.6 M KCl solution is diluted to 1.5 L.

1.5 L = 1500 mL

$M_1V_1 = M_2V_2$

$M_2 = \frac{M_1V_1}{V_2} = 1.6\,M\,\frac{25\,mL}{1500\,mL}$

$= \boxed{0.027\,M}$ (2 s.f.)

[15 pt] 17. A titration experiment uses 14.65 mL of 0.1120 M sodium hydroxide (NaOH) to neutralize 25.00 mL of the triprotic acid phosphoric acid (H_3PO_4). What is the concentration of the acid?

$H_3PO_4 + 3NaOH \rightarrow 3H_2O + Na_3PO_4(aq)$

$M = \frac{\#\ mol\ acid}{L\ acid} = \frac{(0.1120\ mol\ NaOH)(0.01465\ L)\left(\frac{1\ mol\ H_3PO_4}{3\ mol\ NaOH}\right)}{0.02500\ L}$

$= \boxed{0.02187\,M}$

(4 s.f.)