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## **Sample Question Solutions for the Breaking Bonds Round Test**

### **Physical Properties – Easy**

1. What are the dominant intermolecular forces for each of the following molecules?

Choose between London Dispersion Forces, Covalent Interactions, Gravitational Forces, Dipole – Induced Dipole Forces, Dipole – Dipole Forces, and Hydrogen Bonds

- a. Liquid Nitrogen:

London Dispersion Forces

- b. Water:

Hydrogen Bonds

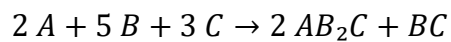
- c. Carbon Dioxide:

London Dispersion Forces

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### Kinetics – Easy

2. Write the rate law for the following reaction given the following details. Assume the rate constant is 1.



You know the reaction is:

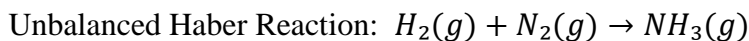
- first order with respect to A
- second order with respect to B
- zeroth order with respect to C

$$\text{rate} = k[A][B]^2$$

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### Stoichiometry – Medium

3. The Haber Reaction is a reaction used to synthesize ammonia (NH<sub>3</sub>), which is a common component of fertilizers. Consider the **unbalanced** Haber Reaction below. You are given 8.74 g of N<sub>2</sub>(g) and 31.47 L of H<sub>2</sub>(g) at STP (0 °C, 1 atm). Assuming the reaction goes to completion, how many moles of the excess reagent will be left over? Assume ideal gas behavior.



$$\frac{8.74 \text{ g } N_2}{1} * \frac{1 \text{ mole } N_2}{28.013 \text{ g } N_2} = 0.312 \text{ moles of } N_2 \rightarrow \text{Limiting Reactant}$$

$$\frac{31.47 \text{ L } H_2}{1} * \frac{1 \text{ mole } H_2}{22.4 \text{ L } H_2} = 1.4 \text{ moles of } H_2 \rightarrow \text{Excess Reactant}$$

0.312 moles of N<sub>2</sub> used

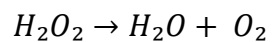
(0.312 moles)\*(3) = 0.936 moles H<sub>2</sub> used

1.4 – 0.936 = 0.464 moles H<sub>2</sub> remaining

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### Redox - Medium

4. Hydrogen peroxide decomposes spontaneously under standard conditions. Below is the **unbalanced** equation for the decomposition of hydrogen peroxide.



- a. List the oxidation states of each element.

H in  $H_2O_2$  is: +1

O in  $H_2O_2$  is: -1

H in  $H_2O$  is: +1

O in  $H_2O$  is: -2

O in  $O_2$  is: 0

Write the balanced oxidation and reduction **half reactions** in an **acidic medium**.

Reduction:  $H_2O_2 + 2 H^+ + 2 e^- \rightarrow 2 H_2O$  or  $H_2O_2 + 2 H_3O^+ + 2 e^- \rightarrow 4 H_2O$

Oxidation:  $H_2O_2 \rightarrow + O_2 + 2 e^- + 2 H^+$  or  $H_2O_2 + 2 H_2O \rightarrow + O_2 + 2 e^- + 2 H_3O^+$

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### Acid-Base Equilibrium – Hard

5. The ocean floor in Krypton consists of hydrothermal vents and high water pressure. Under temperatures of 150 °C and pressures of about .47 MPa, the self-ionization of water has a  $pK_w$  of 11.64.

An unknown, diprotic acid,  $H_2A$ , may be released from these hydrothermal vents. **The concentration of the acid in the area is 0.01 M.** Calculate the pH of the surrounding region given the following information about the acid.

- $K_{a1} = 4.5 \times 10^{-7}$
- $K_{a2} = 4.7 \times 10^{-11}$

	$H_2X$	$\rightarrow$	$HX$	$H^+$
Initial	.01		0	$\sqrt{10^{-11.64}}$
Change	-x		+x	+x
Final	.01-x		+x	$1.5136 \times 10^{-6} + x$

$$\frac{x(1.5136 \times 10^{-6} + x)}{.01 - x} = 4.5 \times 10^{-7}$$

$$x = 6.611 \times 10^{-5}$$

$$H^+ = 1.5136 \times 10^{-6} + 6.611 \times 10^{-5} = 6.7621 \times 10^{-5}$$

$$pH = -\log(H^+) = -\log(6.7621 \times 10^{-5}) = 4.17$$

$$pH = 4.17$$

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### Thermodynamics - Hard

6. 31.4 g of ice is added to 100 g of water that is at 66.60 °C in a constant-pressure calorimeter. **At the instant when all the ice has melted**, the final temperature of the water is 23.40 °C. Given that the specific heat,  $C$ , of water is 4.18 J/g°C, what is the experimental value for the specific heat of fusion,  $\Delta H_f$ , of ice? **Report your answer in kilo-joules per mole.**

$$(100\text{g})(66.6^\circ\text{C} - 23.4^\circ\text{C})(4.18\text{K/g}^\circ\text{C}) = 18057.6\text{Joules gone to melting the ice}$$

$$(18507.6\text{J}) * (18\text{g/mol}) / (31.4\text{g}) = 10351.5\text{ Joules/mol}$$

$$\underline{10.35\text{ kJ/mole}}$$