HARD PACKET 1 Team ID: _____

1. A 18.1 L closed vessel contains 2.53 g H_2O, 5.34 g CO_2, and 3.60 g SO_3. At 50˚C, what is the pressure in the vessel (in atm)? Assume these gasses behave ideally.

2. At 500 K, the equilibrium constant is defined as $K_p = 2.9 \times 10^3$ for the reaction $SbCl_{3\,(g)} + Cl_{2\,(g)} \rightleftharpoons SbCl_{5\,(g)}$. A container holds 0.08 atm $SbCl_3$, 1.0×10^{-5} atm Cl_2, and 0.09 atm $SbCl_5$. Calculate the partial pressures (in atm) of the gasses at equilibrium.

3. At 450°C, $K_P = 6.5 \times 10^{-6}$ for the thermal decomposition of NO_2. Here is the corresponding reaction: $2NO_{2\,(g)} \rightleftharpoons 2NO_{(g)} + O_{2\,(g)}$.

   If a reaction vessel at this temperature initially contains only 0.500 atm NO_2, what will be the partial pressures of NO_2, NO, and O_2 in the vessel when equilibrium has been attained?

HARD PACKET 2 Team ID: _____

1. The solubility of silver carbonate in water at 27°C is 1.3×10^{-4} M. What is the solubility of Ag_2CO_3 at 27°C in (a) 0.10 M $AgNO_3$ and (b) 0.10 M Na_2CO_3? (Please ignore the reactions between H_2O and CO_3^{2-}, and between Ag^+ and OH^-.)

2. A 25 mL of 0.25 M aqueous solution of $HCOOH$ is titrated with 0.1 M aqueous solution of $NaOH$ at 25°C. What is the pH of the solution at the equivalence point at 25°C?
   Given: For $HCOOH$, $K_a = 1.7 \times 10^{4}$ at 25°C.

3. An electron is confined to a 3-D cubic box with $L_x = L_y = L_z = 8.0$ Å. Calculate the velocity (speed), in m/s, of the electron when it occupies the fourth excited energy level.

HARD PACKET 3 Team ID: _____

1. Salinity (S) is defined as the weight percentage of total dissolved substances in seawater. It has units of ppt (parts per thousand, ‰). 1 ppt = 1 g/kg. The specific gravity (sg) of seawater is the ratio of its density to pure water at the same temperature. Assume pure water has a density of 1.00 g/mL. Calculate the weight (in g) of NaCl needed to convert 1.00 L, 34 ppt seawater to 35 ppt at room temperature.

Table 2. Specific gravity and refractive index as a function of seawater's salinity of seawater. The bold rows (34-36 ppt) represent the range usually encountered in the open ocean.

Salinity (ppt)	Specific Gravity at 25° C	Refractive Index (20° C)
0	1.0000	1.33300
30	1.0226	1.33851
31	1.0233	1.33869
32	1.0241	1.33886
33	1.0249	1.33904
34	**1.0256**	**1.33922**
35	**1.0264**	**1.33940**
36	**1.0271**	**1.33958**
37	1.0279	1.33976
38	1.0286	1.33994
39	1.0294	1.34012

HARD PACKET 3 Team ID: _____

2. A two bulbed flask contains 7 particles. What is the probability of finding 6 particles on one side and 1 particle on another side. (Rounded to 3 decimal places)

3. Initially, 1 mol of ideal gas A is in a container in which the following reaction is happening at 298 K, and the pressure inside of the container is 1.0 atm.

$$A(g) \rightleftharpoons B\ (g)$$ (B is also an ideal gas)

Given that $G_A^\circ = 10\ kJ/mol$, $G_B^\circ = 5\ kJ/mol$, when $n_A = 0.7\ mol$, calculate the total G in the system (round to 3 decimal places):

HARD PACKET 4 Team ID: _____

1. Consider a liquid mixture containing 2 mol of liquid A and 3 mol of liquid B at 25℃. Determine the total equilibrium vapor pressure exerted by two ideal gases A and B (Round to 3 decimal places) ($\Delta G_{vap,\,A}^{\circ}(25\ ℃) = 2.0\ kJ/mol$, $\Delta G_{vap,\,B}^{\circ}(25\ ℃) = 2.4\ kJ/mol$).

2. An electrochemical cell is constructed with a piece of copper wire in a 1.00 M solution of $Cu(NO_3)_2$ and a piece of chromium wire in a 1.00 M solution of $Cr(NO_3)_3$.

   The standard reduction potentials for $Cr^{3+}_{(aq)}$ and $Cu^{2+}_{(aq)}$ are:

   $Cr^{3+}_{(aq)} + 3e^- \rightarrow Cr_{(s)}$ -0.744 V

   $Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$ 0.340 V

   The cell is allowed to operate until the $[Cu^{2+}] = 0.10$ M. Calculate the cell potential at this concentration.

3. Calculate the work done by 10 g of O_2 expanding isothermally at 20°C from 1 to 0.3 atmospheres of pressure, assuming O_2 behaves as an ideal gas.

HARD PACKET 5 Team ID: _____

1. If given an initial C_5H_6 concentration of 0.0400 M, a final concentration of 0.0230 M, and a half-life of 12 minutes, what is the second-order rate constant, *k*, in s^{-1}?

2. Given a particle in the quantum ground state, find (symbolically) the probability density $P(x) = \left|\Psi_n(x)\right|^2$ of this quantum particle as a function of its position in the box?

$$\Psi_n(x) = \sqrt{\frac{2}{L}}\, sin(\frac{n\pi x}{L})$$

3. For a given reaction, its equilibrium constant at 25°C is 5.4×10^5. At 540°C, its equilibrium constant has decreased by 98%. Find the standard change in enthalpy of the reaction in kJ/mol.

HARD PACKET 6 Team ID: _____

1. List the locations that a particle in its fourth excited state in a 1-dimensional box is mostly likely to be found in terms of L, the length of the box.

2. The specific heat capacity for iron is $0.451\ J/g^{\circ}C$. For nickel, it takes 273 J of heat to raise the temperature of a 5.04 g block from $25^{\circ}C$ to $147^{\circ}C$. Which substance, iron or nickel, would require more heat to raise its temperature by one degree Celsius, assuming both are present in the same amount?

3. You measure the root-mean-square speed of 5 mol of ideal gas molecules to be 301.25 m/s. The pressure inside your 4.5 L container is 27.8 atm. What is the identity of this gas?

HARD PACKET 7 Team ID: _____

1. Given the following information:
   $2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$, ΔH = -2599 kJ/mol
   Heat of Formation of H_2O = -286 kJ/mol
   Heat of Formation of CO_2 = -393.5 kJ/mol

   Calculate the enthalpy of the following reaction:
   $\frac{2}{5}C + \frac{1}{5}H_2 \rightarrow \frac{1}{5}C_2H_2$

2. You start with an unknown concentration of an aqueous H_2CO_3 solution. When you perform a titration, the acid-base indicator changes color after adding 40 mL of the H_2CO_3 solution to 50 mL of a 0.1 M KOH solution.
    a. What is the concentration of the H_2CO_3 solution?

    b. If bromophenol blue ($pK_a = 4.1$) is used as the indicator, how many milligrams of $Al(OH)_3$ could theoretically be produced if Al^{3+} ion was added at the moment the indicator changes color? Assume that Al^{3+} only interacts with the hydroxide ion.

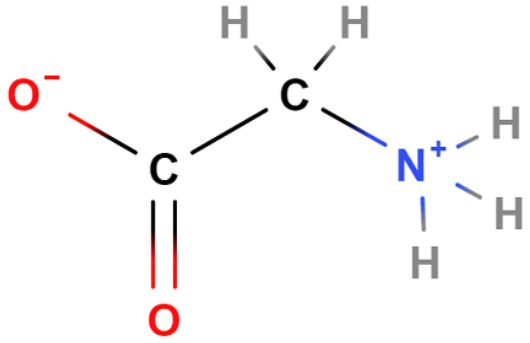
    c. In the titration curve for this titration, how many points on the plot have a slope that cannot be calculated?

3. An ideal gas consisting of atoms of an unknown element exhibits specific properties under controlled conditions. The gas's root-mean-square velocity is 432.79 m/s. When one mole of this gas is contained in a 24.94-L container, it exerts a pressure of one bar.
    a. Determine the unknown element.

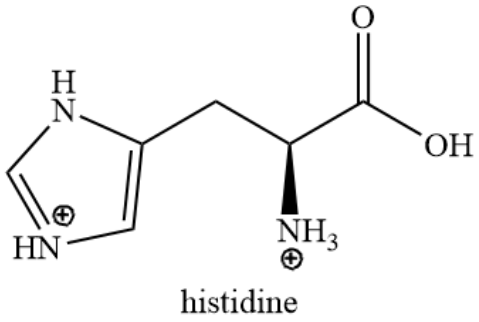
    b. Estimate the average distance between atoms in the gas in Angstroms (Å). Use the volume of a cube in your solving process.

HARD PACKET 8 Team ID: _____

1. The isoelectric point of a zwitterion is the pH at which the molecule is overall neutral. For example, glycine has an isoelectric point of pH 6. Which of the following is likely to be the isoelectric point of histidine? The two molecules are shown below. Given: $pK_a(\text{—}COOH) = 1.82, pK_a(\text{—}NH_3^+) = 9.17, pK_a(imidazole) = 6.00.$



Glycine (left)



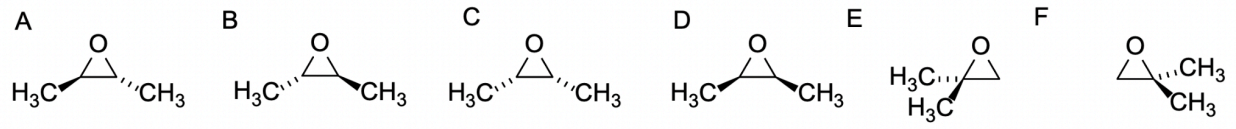
histidine

   a. 1.82
   b. 3.92
   c. 6.00
   d. 7.59
   e. 9.17

2. Compound A is composed entirely of carbons and hydrogens. The combustion of 1 mol of compound A consumes 7.5 mol O_2 to form 5 mol CO_2 and 5 mol H_2O. Give the molecular formula of A.

HARD PACKET 8 Team ID: _____

3. For the following pairs of compounds indicate whether they are: **structural** isomers, **diastereomers**, **enantiomers**, or **identical**.



A & B: _____ B & C: _____

C & D: _____ D & E: _____

E & F: _____

HARD PACKET 9 Team ID: _____

1. The purity of copper sulfate can be determined by iodometry. A sample of $CuSO_4 \cdot 5H_2O$ weighing *w* grams is dissolved in enough H_2O. Enough KI solution is then added, and the reaction $2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$ occurs. Using starch as an indicator, the solution is then titrated with a *c* mol/L sodium thiosulfate ($Na_2S_2O_3$) standard solution, which reduces I_2 to I^-. *V* mL titrant is added before the solution turns from blue to milky white. What is the % purity of the sample? Express in terms of *w*, *c* and *V*.

2. In the last question, KSCN is added at around the titration endpoint to convert CuI to $Cu(SCN)_2$. This is because CuI absorbs I_2 in the solution. What would happen if KSCN is not added?
    a. The result would be higher than the true purity.
    b. The result would be lower than the true purity.
    c. The result would still be accurate.
    d. Cannot be determined.

3. A gas expands by an isothermal, reversible process. The volume of the gas changed from 40 L to 50 L. Calculate the heat transferred to the gas system.