1. Multiple choice, **select 1 answer only**. Do *all 12* questions (2 points each, 24 total):

(i) Temperature is,

(c) the average kinetic energy

(ii) Change in enthalpy is,

(b) the energy flow (as heat) of a system at constant pressure

(iii) Ammonium nitrate is a fertilizer and also one component of an explosive popular with terrorists (Timothy McVeigh used this compound in the Oklahoma City bombing of 1995). What is its chemical formula?

(a) $NH_4\,NO_3$

(iv) What is the correct IUPAC name of Hg_2S?

(b) mercury (I) sulfide

(v) 12.0 moles of a gas (SO_2) under *non-ideal conditions* was measured to have a pressure of 1.00 x 10^2 atm in a 3.00 L container. What is the temperature? The van der Waals constants for SO_2 are a = 6.865 L^2atm/mol^2 and b = 0.05679 L/mol.

c) 494 K

NOTE: this question requires the van der Waals equation, which is,
Solving for T gives,

$$\left(P + \frac{n^2 a}{V^2}\right) \cdot (V - nb) = nRT$$

$$T = \frac{\left(P + \frac{n^2 a}{V^2}\right)(V - nb)}{nR}$$

$$= \frac{\left(100.\text{atm} + \frac{(12.0\text{mol})^2 (6.865\text{L}^2\text{atm/mol}^2)}{(3.00\text{L})^2}\right)(3.00\text{L} - (12.0\text{mol})(0.05679\text{L/mol}))}{(12.0\text{mol})(0.08206\text{Latm/molK})}$$

(vi) The vapour pressure of a solvent is the amount of gaseous molecules over an open vessel of the solvent. A 50/50 mixture of benzene and toluene has 46.7 Torr of benzene and 13.5 Torr of toluene at STP. What is the pressure of air over this mixture?

e) 699.8 Torr

NOTE: this is a Dalton's Law question, which states that $P_{total} = P_1 + P_2 + ...$
Therefore, if P_{total} is at atmospheric pressure, or 760. Torr, and the partial pressures of two components of the components are 46.7 and 13.5 Torr, the remainder (*i.e.* the air) must have a pressure of 760. - 46.7 - 13.5 = 699.8 Torr (the 760 is actually an exact number because it is in the definition of STP).

(vii) Which of the following is the best conductor of electricity by ionic conduction through a solution (*i.e.* what gives the most ions)? Assume all solutions have the same molarity.

(e) both (a) and (c)

NOTE: a strong acid is a strong electrolyte (although a strong electrolyte is not necessarily a strong acid)

(viii) Consider the reaction: $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

(b) this is a precipitation reaction

(ix) Which one of the following is NOT true of an ideal gas?

(e) gas molecules are assumed to never hit the walls of their container

(x) 100. g of an iron ore (Fe_3O_4) was converted to iron by reacting with excess carbon, according to the following reaction:

$$Fe_3O_4(s) + 2\,C(s) \rightarrow 3\,Fe(s) + 2\,CO_2(g)$$

If 53.0 g of iron was isolated, what is the percent yield?

(b) 73.2%

NOTE: theoretical yield =
(100. g Fe_3O_4)(1 mol/231.55g)(3 mol Fe/1 mol Fe_3O_4)(55.85 g Fe/mol) = 72.36 g
% yield = 53.0 g/72.36 g * 100% = 73.2%

(xi) Charles's Law relates the behaviour of an ideal gas as temperature varies. By this law,

(e) both (b) and (c) (as temperature increases, volume increases (at constant pressure), and at absolute 0 (0 K), the volume of an ideal gas is 0

(xii) A coffee cup calorimeter has 100.00 g of water in it. Assuming an adiabatic system (there is no heat loss to the surroundings), what is the heat capacity (C_p)of the calorimeter?

(e) 418 J °C^{-1}

NOTE: this is 100.00 g * 4.18 J °C^{-1} g^{-1} (specific heat of water)

2. In the space provided, answer **2 of the following 3** questions. If you need more room, use the back of this page. (5 points each, 10 points total)

(a) Using the Kinetic molecular theory, explain why pressure increases as temperature increases (at constant volume). Also explain the origin of the pressure correction term ($P + n^2a/V^2$) in the van der Waals formula for a real gas, and state whether this *qualitatively* changes your explanationof the pressure-temperature relationship. (5 points)

The following pieces of information were required:
- pressure arises from collisions between the particles and the walls of the container
- temperature is the average kinetic energy so as temperature increases, average K.E. increases, and therefore the average speed of the gas molecules (because $E = \frac{1}{2}mv^2$)
- the increase in speed will cause more collisions with the wall, therefore P increases

- the pressure correction term takes into account intermolecular forces (which are attractive and reduce the observed pressure)
- this does not qualitatively change the P-T relationship, because it's more dependent on the kinetic energy than anything else

(b) A 100. g piece of slag iron at its melting point (2082 K) was dropped into 1.000 kg of water at room temperature (298 K). What is the final temperature of the water and iron? Specific heats are: s_{water} = 4.18 J K^{-1} g^{-1}; s_{iron} = 0.45 J K^{-1} g^{-1}. (5 points)

$q = sm\Delta T$
$q_{H2O} = -q_{Fe}$
therefore: $s_{H2O}m_{H2O}\Delta T_{H2O} = -s_{Fe}m_{Fe}\Delta T_{Fe}$ But the two T_f are the same!
$(4.18\text{ J g}^{-1}\text{K}^{-1})(1000.\text{g})(T_f - 298\text{K}) = -(0.45\text{ J g}^{-1}\text{K}^{-1})(100.\text{g})(T_f - 2082\text{K})$

Rearranging and solving for Tf gives: $(4180\text{ J K}^{-1} / 45\text{ J K}^{-1})(T_f - 298\text{K}) = 2082 - T_f$
T_f = 317 K (or 320 if you're a sig. fig. stickler)

(c) 1.50 g of sodium hydroxide (NaOH (*s*)) was added to 100.00 mL of aqueous sulfuric acid (H_2SO_4 (*aq*), concentration 0.250 *M*). Assuming the addition of NaOH does not change the volume of the solution, calculate the amount of excess acid or base left in the solution after the reaction takes place. (5 points)

A balanced equation could be,

$$H_2SO_4\ (aq) + 2\ NaOH\ (aq) \rightarrow Na_2SO_4\ (aq) + 2\ H_2O\ (l)$$

which shows that H2SO4 and NaOH are in a 2:1 ratio. You could carry on from here, but I prefer the following method:

Calculate moles of acid (H^+): $H_2SO_4\ (l) \rightarrow 2\ H^+\ (aq) + SO_4^{2-}\ (aq)$

n_{H+} = (0.100 L)(0.250 mol/L)(2 mol H^+ / 1 mol H_2SO_4) = 0.0500 mol H^+

n_{OH-} = (1.50 g) / (40.00 g/mol) = 0.0375 mol OH^-

OH^- is limiting, therefore, there is 0.0500-0.0375 = 0.0125 mol of H^+ left in solution.
(this could also be reported as 0.00625 mol of H_2SO_4, or 0.6 g H_2SO_4, or 0.125 *M* H^+, or 0.0625 *M* H_2SO_4)