CHEM106 Section 001 Problem Set 1 Answer Key

① Formula for Kinetic Energy: $E = \frac{1}{2} m v^2$

i) 1 Joule = $\frac{1\,kg\,m^2}{s^2}$

From the problem: 25 km/s = velocity (v)
2.5×10^5 kg: mass of spaceship

$$E = \frac{1}{2}(2.5 \times 10^5\,kg)\left(\frac{25\,km}{s} \times \frac{1000\,m}{km}\right)^2$$

$$E = \frac{1}{2}(2.5 \times 10^5\,kg)\left(\frac{6.25 \times 10^8\,m^2}{s^2}\right)$$

$$E = 7.81 \times 10^{13}\,\frac{kg\,m^2}{s^2} = \boxed{7.81 \times 10^{13}\,J}$$

ii) From Google: Mass of earth = 5.972×10^{24} kg

We are trying to determine the density, which is in $\frac{g}{cm^3}$

The problem tells us that the nucleus is a sphere and the units of volume are cubic centimeters

$$1.5 \times 10^{-5}\,pm \times \frac{1\,cm}{1 \times 10^{-2}\,m} \times \frac{1\,m}{1 \times 10^{12}\,pm} = 1.5 \times 10^{-15}\,cm$$

Volume of a sphere $= \frac{4}{3}\pi r^3 = \left(\frac{4}{3}\right)\pi\left(1.5 \times 10^{-15}\,cm\right)^3$

$= 1.41 \times 10^{-44}\,cm^3$

Density is in g/cm^3, so:

Mass of the earth is:

$5.97 \times 10^{24}\ Kg \times \frac{1000g}{Kg} = 5.97 \times 10^{27}\ g$

Therefore, the density would be:

$$Density = D = \frac{mass}{volume} = \frac{5.97 \times 10^{27}\ g}{1.41 \times 10^{-44}\ cm^3} = \boxed{\frac{4.23 \times 10^{71}\ g}{cm^3}}$$

iii) In this problem, we are mixing a base with it's conjugate acid and letting them sit @ equilibrium.

This problem could be done using the K_B for the reaction

$$NH_3 + H_2O \rightleftharpoons NH_4^{\oplus} + OH^{\ominus}$$

$$K_B = \frac{[NH_4^+][OH^-]}{[NH_3]}$$

We know the molarity of NH_3 and NH_4^+, so plug and chug after rearranging to solve for $[OH^-]$

$$[OH^-] = \frac{K_B [NH_3]}{[NH_4^+]}$$

$$[OH^-] = \frac{(1.8 \times 10^{-5})(0.125M)}{(0.3M)}$$

$$\boxed{[OH^-] = 6.48 \times 10^{-7}}$$

iv) The titration of methylamine with H_3O^+ has a chemical reaction that looks like:

$$CH_3NH_2 + H_3O^+ \longrightarrow CH_3NH_3^+ + H_2O$$

At the equivalence point, all of the methylamine has been converted to methylammonium, so the major species ~~is~~

$$\boxed{CH_3NH_3^{\oplus}}$$

② i) Use the graph! The equivalence point is reached when 10mL of base has been added and the pH is $\boxed{8.0}$

ii) If the equivalence point is reached @ 10mL, then 25% of the equivalence point would be 0.25 × 10mL = 2.5mL. The pH @ 2.5mL of base added is ~$\boxed{3.5}$

iii) Halfway to the equivalence point, the pH would be $\boxed{4}$

iv) 75% of the way to the equivalence point, the volume of base added would be 7.5mL and the pH is $\boxed{4.5}$

(3) Both the acid and the base are the same concentration. We had 50mL of acid and added 55mL of base. We have neutralized all of the acid and have 5mL of ^-OH left over.

New total volume: 105mL (volume of acid + volume of base)
moles of base in excess: $0.005L \times \frac{0.02 \text{ mol } ^-OH}{L} = 1\times10^{-4}$ moles OH^-

$pH + pOH = 14$

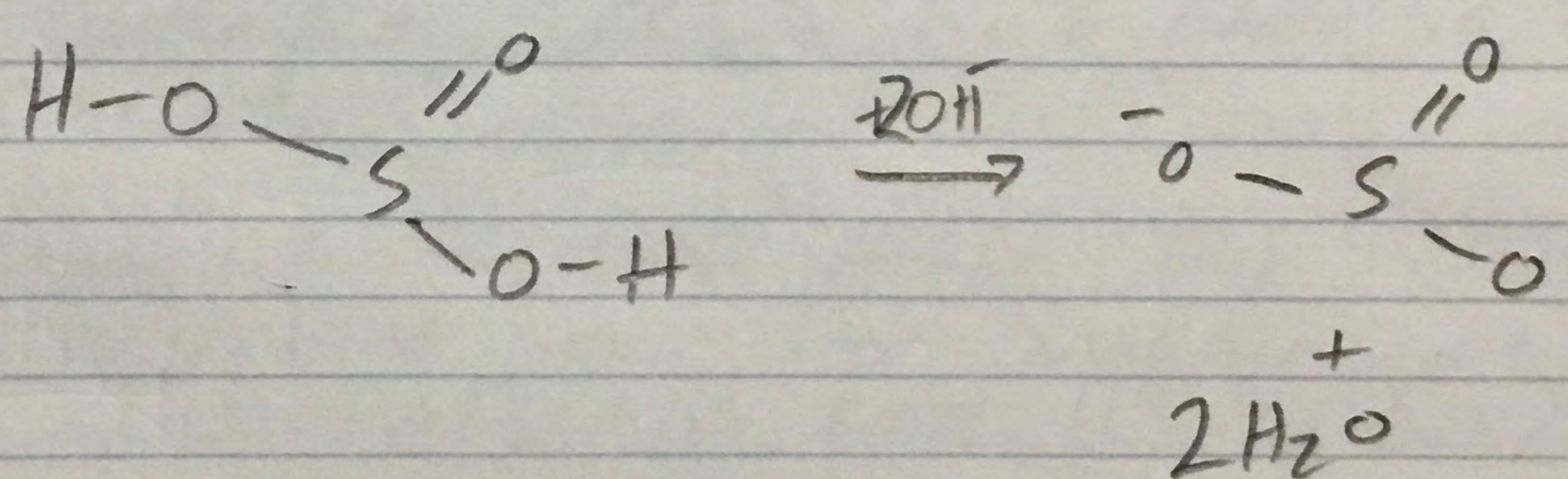
$pH = 14 - pOH$

$pOH = -\log[OH^-] = -\log\left(\frac{1\times10^{-4} \text{ moles } OH^-}{0.105L}\right)$

$pOH = 3.02$

$pH = 14 - 3.02 = \boxed{10.98}$

(4) From the problem, you can see that there are 2 acid protons



Just like problem 2, the first endpoint is @ the steepest slope, so 50mL of ^-OH added.

Halfway to this volume is pK_{A1}, so when 25mL of ^-OH has been added, the pH is $\boxed{2}$

Using the same logic for the second proton, the endpoint volume is 100mL of ^-OH added so the halfway point would be 75mL of ^-OH added. The pH is $\boxed{7}$

(5) i) If the interaction energy is proportional to $1/r^2$ we know we have an ion-dipole interaction.

Chloromethane isn't an ion, so (a) is out
Na^+ is an ion and H_2O is a dipole. This is the correct answer.

B

ii) An interaction energy proportional to $1/r^3$ is a dipole-dipole interaction. Find 2 dipoles or polar molecules

Chloromethane is polar, and would interact in liquid phase.

Choice A is correct

Ionic solid isn't a dipole so (B) is incorrect

Bromine molecules (Br_2) isn't polar so (C) is incorrect.

Chloromethane in the solid phase has some peculiarities that you are unaware of, and since chloromethane is polar, **Choice C is correct**

iii) We are looking for Dipole/Induced dipole or London Force interactions.

Chloromethane is polar so (A) is incorrect so is (B)

Li^{+} is an ion and H_2O is a dipole so (C) is incorrect.

Na^{+} and H_2O, same thing.

This doesn't have an answer that makes sense according to what we talked about in class.

Free points!!! yay!

iv) Highest molar mass = Highest boiling point since All but choice (C) are polar

Answer = (B)

v) **Hydrogen bonding is the strongest interaction**