

CHEMISTRY 20B
Professor: Daniel Neuhauser
Midterm Exam # 1
Thursday, February 3, 2011

NAME: Alex August-Schmidt

Discussion 517 (Loomar)

This exam consists of six questions with multiple parts. Make sure your exam has **12 different numbered pages**.

If you run out of space working a problem, use the back of a page and indicate on the front that you have done so.

Before starting, write your name on every page.

A periodic table and a page of some useful information are included at the end of the exam.

Question	Value	Score
1	20	17
2	15	15
3	20	16
4	20	20
5	20	17
6	25	25
Total	120	110

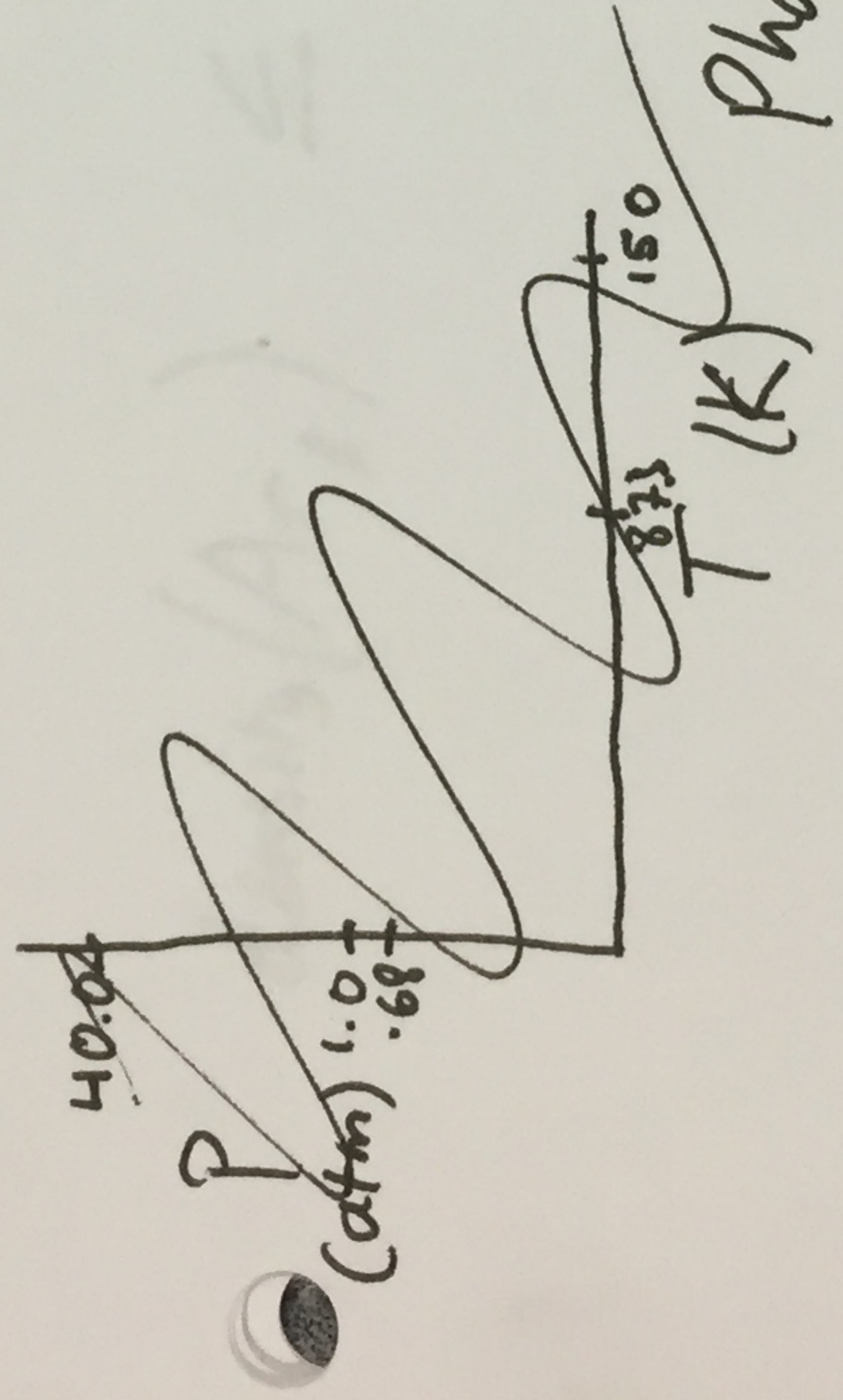
Name Alex August-Schmidt

1. a. (12 points) The following Table gives several important points on the pressure-temperature diagram of Argon:

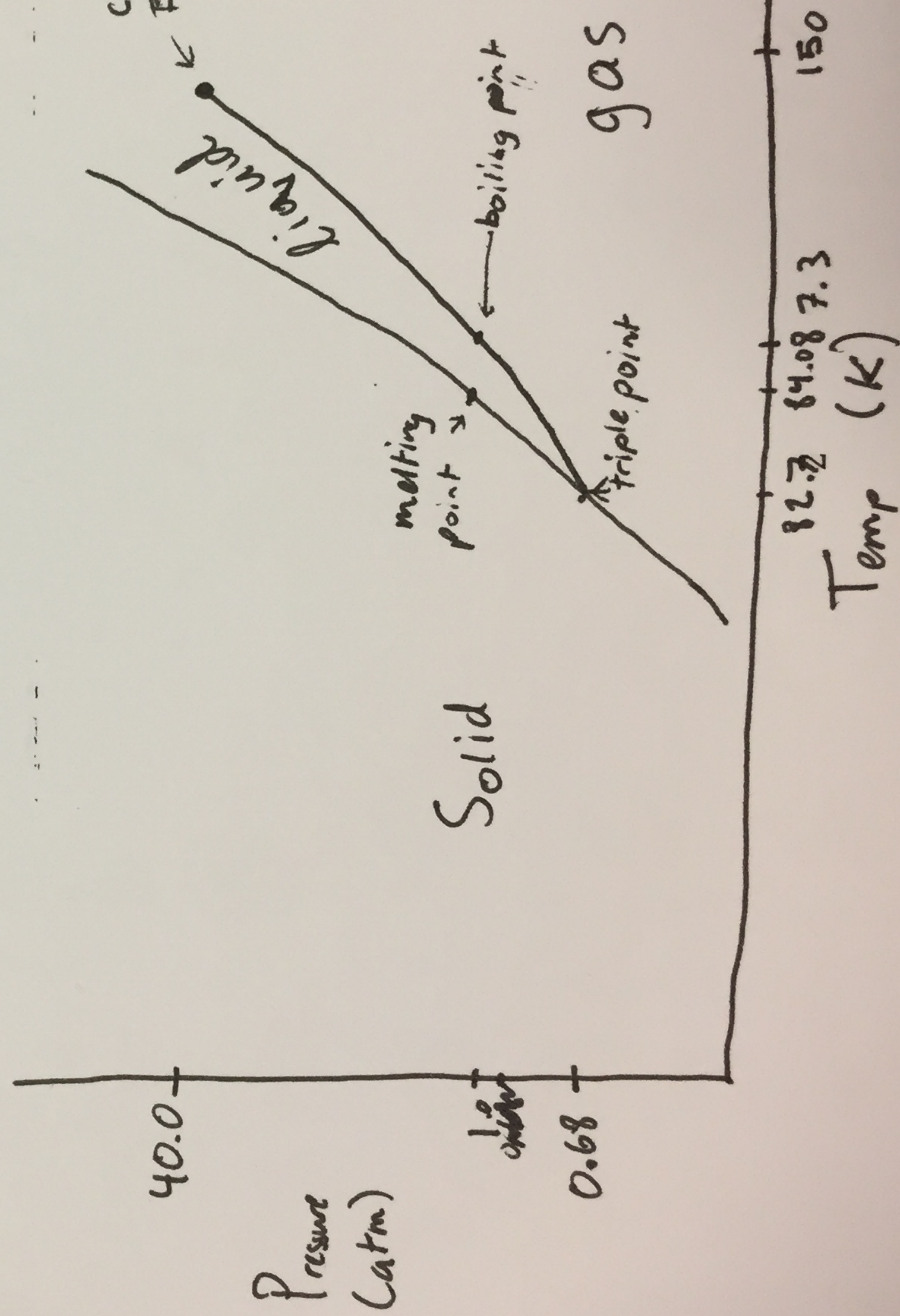
	P(atm)	T(K)
Triple Point	0.68	82.7
Critical Point	40.0	150.0
Normal Boiling Point	1.0	87.3
Normal Melting Point	1.0	84.0

Use this information to sketch the phase diagram of Argon, labeling the axes and showing clearly the stable phase in each region of your diagram.

Phase Diagram of Ar



Phase Diagram of Ar (not to scale)



Name Alex August-Schmidt

b. (8 points) Does liquid Argon have a density equal to, greater than or lesser than solid Argon? Explain why.

Liquid Argon has a density less than solid argon because the slope of the line dividing the solid and liquid phase is positive. *explain more*

$$\text{density}(Ar_l) \leq \text{density}(Ar_s)$$

Piston

2. (15 points) Starting with the first law of thermodynamics, prove that $C_p = C_v + nR$ for an ideal gas.

1st Law: Energy is conserved

$$\Delta U = q + w$$

$$w = F \cdot dz$$

$$w = -P_{ext} dV$$

$$w = -P_{ext} \Delta V$$

$$\Delta U = q - P \Delta V$$

• constant volume, $\Delta V = 0$

$$\Rightarrow \Delta U = q_v - 0$$

$$\Delta U = q_v$$

• constant pressure

$$\Delta U = q + w$$

$$q = \Delta U - w$$

$$q = \Delta U - (-P \Delta V)$$

$$q = \Delta U + P \Delta V$$

$$\Delta H = \Delta U + \Delta(PV)$$

$$H = U + PV$$

$$C = \frac{q}{\Delta T}$$

$$C_p = \frac{q_p}{\Delta T} = \frac{\Delta H}{\Delta T}$$

$$C_v = \frac{q_v}{\Delta T} = \frac{\Delta U}{\Delta T}$$

$$C_p = \frac{\Delta H}{\Delta T} = \frac{\Delta(U + PV)}{\Delta T}$$

$$C_p = \frac{\Delta U}{\Delta T} + \frac{\Delta(PV)}{\Delta T}$$

$$C_p = \frac{\Delta U}{\Delta T} + \frac{\Delta(nRT)}{\Delta T}$$

$$C_p = C_v + nR$$

we define:

$$H = U + PV$$

$$\Delta H = \Delta U + \Delta(PV)$$

$$\Delta H = q + w + P \Delta V + V \Delta P$$

~~w constant pressure:~~

$$\Delta H = q - P \Delta V + P \Delta V + V \Delta P$$

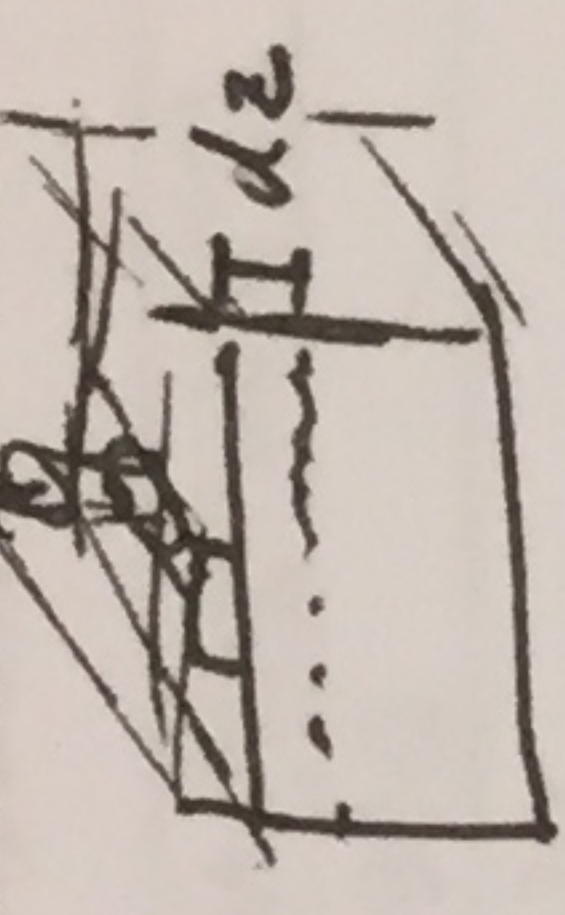
$$\Delta H = q + V \Delta P$$

with constant pressure, $\Delta P = 0$

$$\Delta H = q_p$$

from the ideal gas law, $PV = nRT$

$$\Rightarrow C_p = C_v + nR$$



Name Alex August-Schmidt

3. a. The chart below lists the melting points of two groups of compounds:

Compound	Melting Point(°C)	Compound	Melting Point(°C)
NaF	993	SiF ₄	-90.2
NaCl	801	SiCl ₄	-70
NaBr	747	SiBr ₄	-5.4
NaI	661	SiI ₄	120

ionic

covalent

Explain:

- i) (5 points) Why is the melting point of the sodium halide always higher than that of the corresponding silicon halide?

This is because there are stronger intermolecular interactions in the sodium halides. In solids, ionic interactions are stronger than the covalent interactions in as present in silicon halides.

the silicon halides.

- ii) (5 points) Why does the melting point decrease from NaF to NaI, while it increases from SiF₄ to SiI₄?

It decreases for sodium halides because the difference in electronegativity is decreased. As a result, the strength of the ionic interaction is reduced. However, as the silicon halides increase in size in creases the affect of the induced dipoles by van der Waals interactions. This increased interaction results in more energy to be needed to break the molecules from one another.

b. (10 points) List the order of boiling points of the following species in increasing order and explain the trend.

VDW

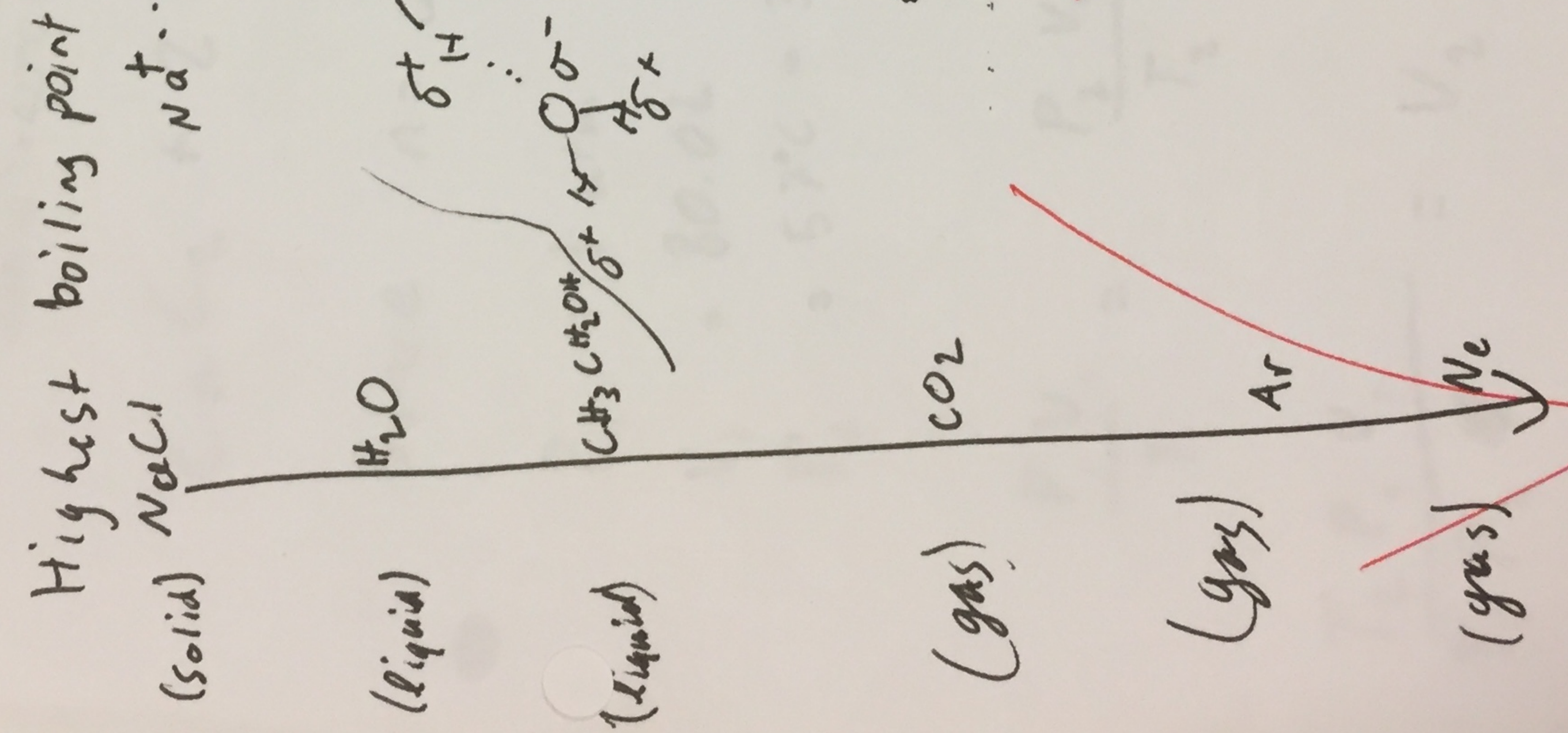
CH₃CH₂OH, CO₂, Ne, NaCl, H₂O, Ar

H bonds -
dipole-dipole
dipole-induced

dipole-ionic
dipole H-BONDS!

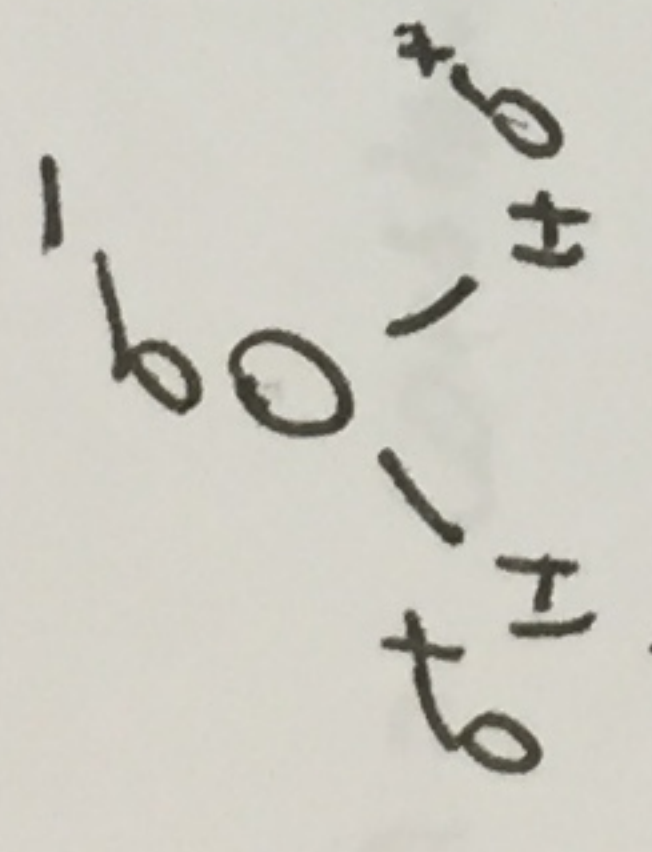
Ar > Ne

OVER ALL TREND: High T_{Boil} = stronger interactions
more
LOW T_B = weak interactions



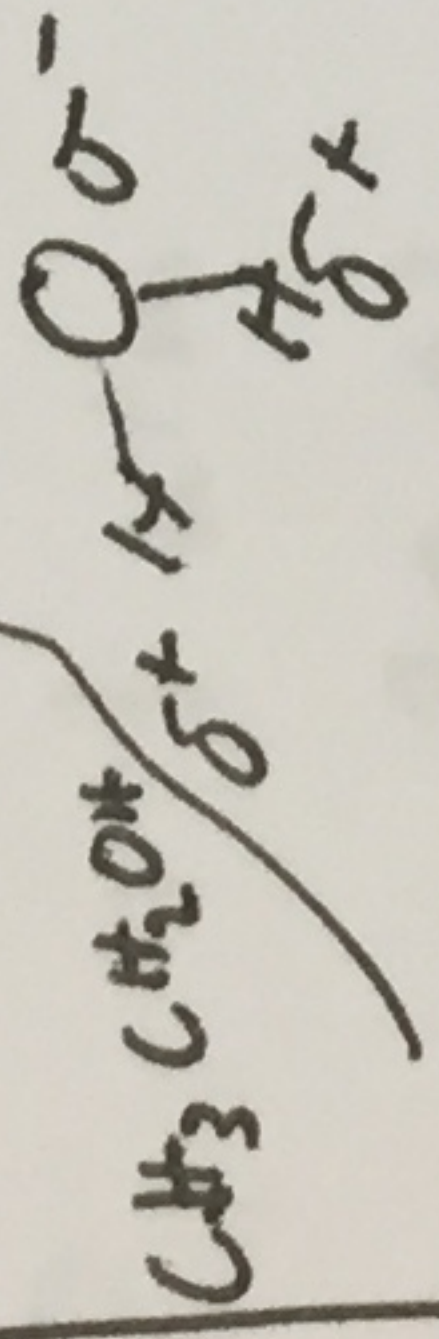
NaCl - Ionic interactions

are the strongest intermolecular interactions. For this reason, NaCl has the highest boiling point



H₂O

H₂O - H-bonds are the strongest dipole-dipole bond. Also there are a large number of them in H₂O, making it the next in order of boiling points



CH₃CH₂OH

are more interactions, however, they are not as strong. CH₃CH₂OH has H-bonds from the O-H bond, dipole-dipole interactions because the C, H, and O atoms do not evenly share electrons, and dipole-induced dipole interactions because it is so big the δ⁻ Carbon may induce an interaction with a δ⁺H. Van der Waals forces are in play, but not to a considerable extent.

CO₂

CO₂ - CO₂ has dipole-dipole interactions

because the C is δ⁺ and each O is δ⁻. These bonds are similar to the H bonds in H₂O, but are in fact much weaker. As a result, CO₂ is a gas at T_{room} and H₂O is a liquid.

Ar

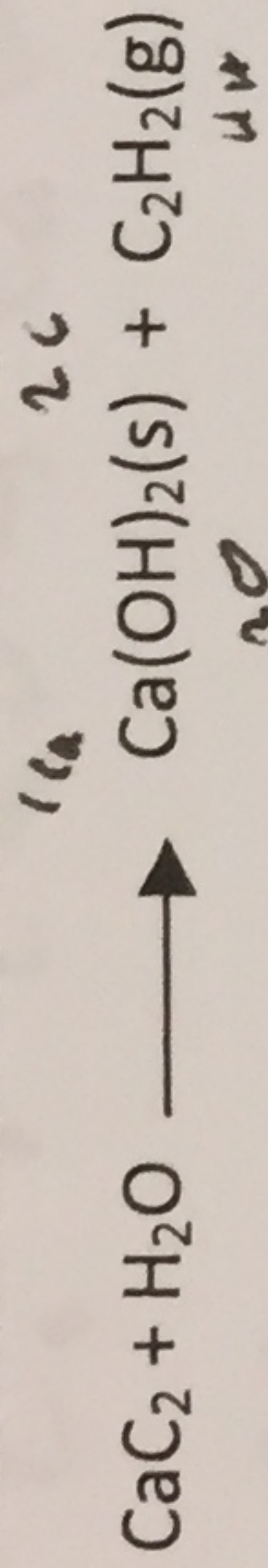
Ar - Argon is a noble gas and only has van der Waals forces in play. These are the weakest of all interactions. It has a complete outer shell, and the electrons are shared evenly.

Ne

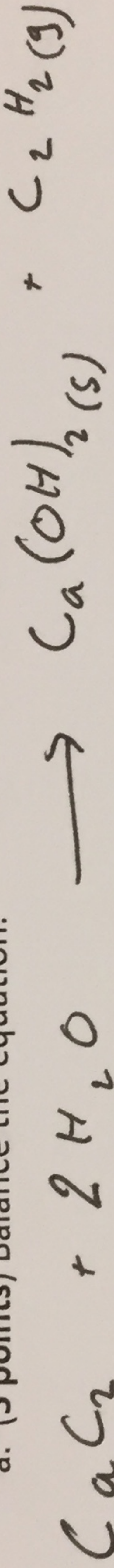
Ne - Neon has even weaker van der Waals interactions because it is smaller, and its outer electron shell has fewer opportunities for a smaller probability that quantum mechanics, the cause of van der Waals, will affect a neighboring atom.

← lowest boiling point

4. The reaction between water and CaC_2 is:

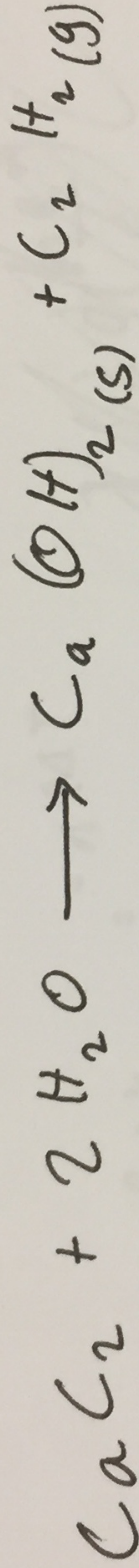


a. (5 points) Balance the equation.



x5

b. (15 points) Certain amount of CaC_2 completely react with water at $T = 57^\circ\text{C}$, $P = 1$ atm and generate 80.0 L of C_2H_2 . If the same amount of CaC_2 completely reacts with water at $T = 427^\circ\text{C}$, $P = 2$ atm, what's the volume of C_2H_2 gas generated in this reaction?



Since $n = \text{constant}$, we can apply the I.G.L.

$$P_1 = 1 \text{ atm}$$

$$V_1 = 80.0 \text{ L}$$

$$T_1 = 57^\circ\text{C} = 330 \text{ K}$$

$$P_2 = 2 \text{ atm}$$

$$V_2 = ?$$

$$T_2 = 427^\circ\text{C} = 700 \text{ K}$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{T_2 P_1 V_1}{T_1 P_2} = V_2$$

$$\frac{(700 \text{ K})(1 \text{ atm})(80.0 \text{ L})}{(330 \text{ K})(2 \text{ atm})} = V_2$$

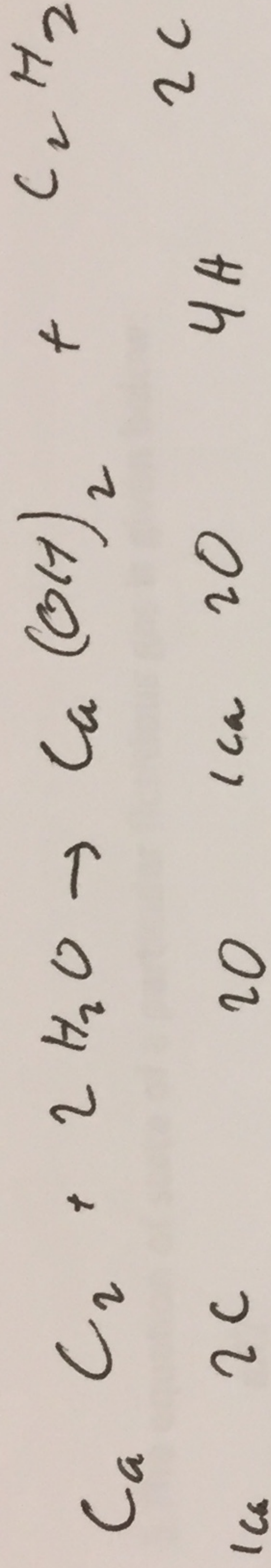
$$\text{ANS } 84.87 \text{ L} = V_2$$

$$\boxed{84.87 \text{ L} = V_2}$$

x5

Name Alex August-Schmidt

4*



$$\int_{V_1}^{V_2} \frac{nRT}{V} dV = \int_{P_1}^{P_2} \frac{nRT}{P} dP = -nRT \ln \left(\frac{P_2}{P_1} \right)$$

$$-P \Delta V = -nRT$$

$$- \frac{nRT}{P} \ln \left(\frac{P_2}{P_1} \right) = \frac{nRT}{P} \ln \left(\frac{P_1}{P_2} \right)$$

$$P(V_1 + V_2) = nRT$$

$$P V_1 - P V_2 = nRT$$

$$P V = \frac{nRT - P V_2}{1}$$

$$P \Delta V = nRT - P V_2$$

5. The equation of state of a particular fictitious gas is given below:

$$p = \frac{nRT}{V-b}$$

a. (10 points) Derive the work done by that fictitious gas for a reversible isobaric (i.e., constant pressure) expansion.

$$\Delta U = q + w$$

Ideal Gas:

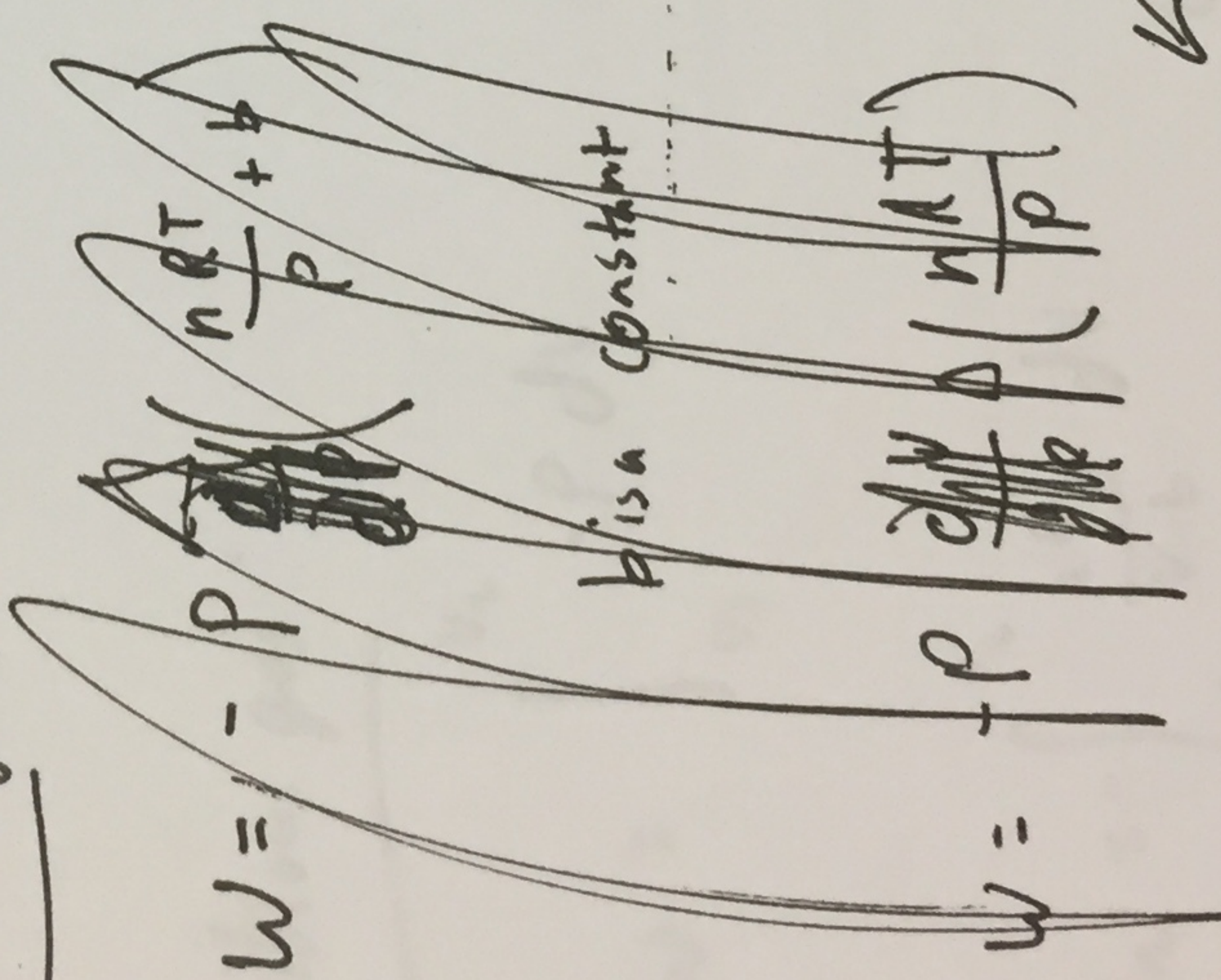
$$\Delta U = q + P\Delta V$$

$$w = -P\Delta V$$

~~$$w = -P\Delta V$$~~

$$w = -nR\Delta T$$

fictitious gas:



$$PV = nRT$$

$$P = \frac{nRT}{V} \quad V = \frac{nRT}{P}$$

$$P = \frac{nRT}{V-b}$$

$$(V-b)P = nRT \quad PV - Pb = nRT$$

$$PV = nRT + Pb \quad PV = nRT + Pb$$

$$PV = nRT + Pb \quad P\Delta V = nR\Delta T + P\Delta b$$

$$w = -(nR\Delta T + P\Delta b)$$

$$w = -nR\Delta T - P\Delta b$$

~~$w = -nR\Delta T - P\Delta b$~~

A

$$I_g: -nRT \ln \frac{v_2}{v_1} = W$$

Name Alex August-Schmidt

b. (10 points) Derive the work done by that fictitious gas for a reversible isothermal (i.e., constant temperature) expansion.

$$P = \frac{nRT}{V-b}$$

Ideal gas:

$$W = \int_{v_1}^{v_2} -P dv$$

$$W = - \int_{v_1}^{v_2} \frac{nRT}{v} dv$$

$$W = -nRT \int_{v_1}^{v_2} \frac{1}{v} dv$$

$$W = -nRT \ln \left(\frac{v_2}{v_1} \right)$$

Fictitious gas:

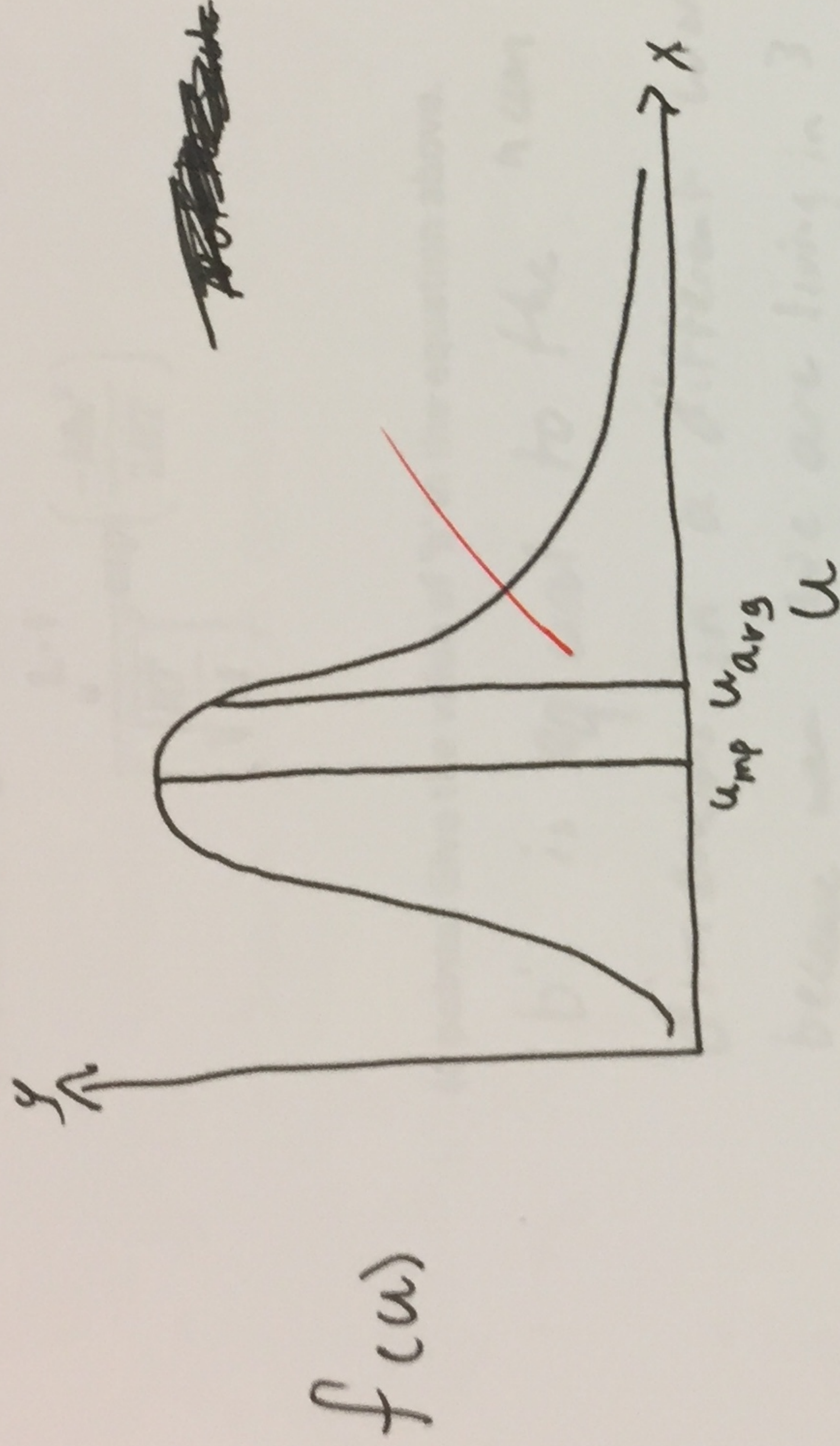
$$W = \int_{v_1}^{v_2} -P dv$$

$$W = - \int_{v_1}^{v_2} \frac{nRT}{v-b} dv = -nRT \int_{v_1}^{v_2} \frac{1}{v-b} dv$$

$$W = -nRT \ln \left(\frac{v_2-b}{v_1-b} \right)$$

Name Alex August-Schmidt

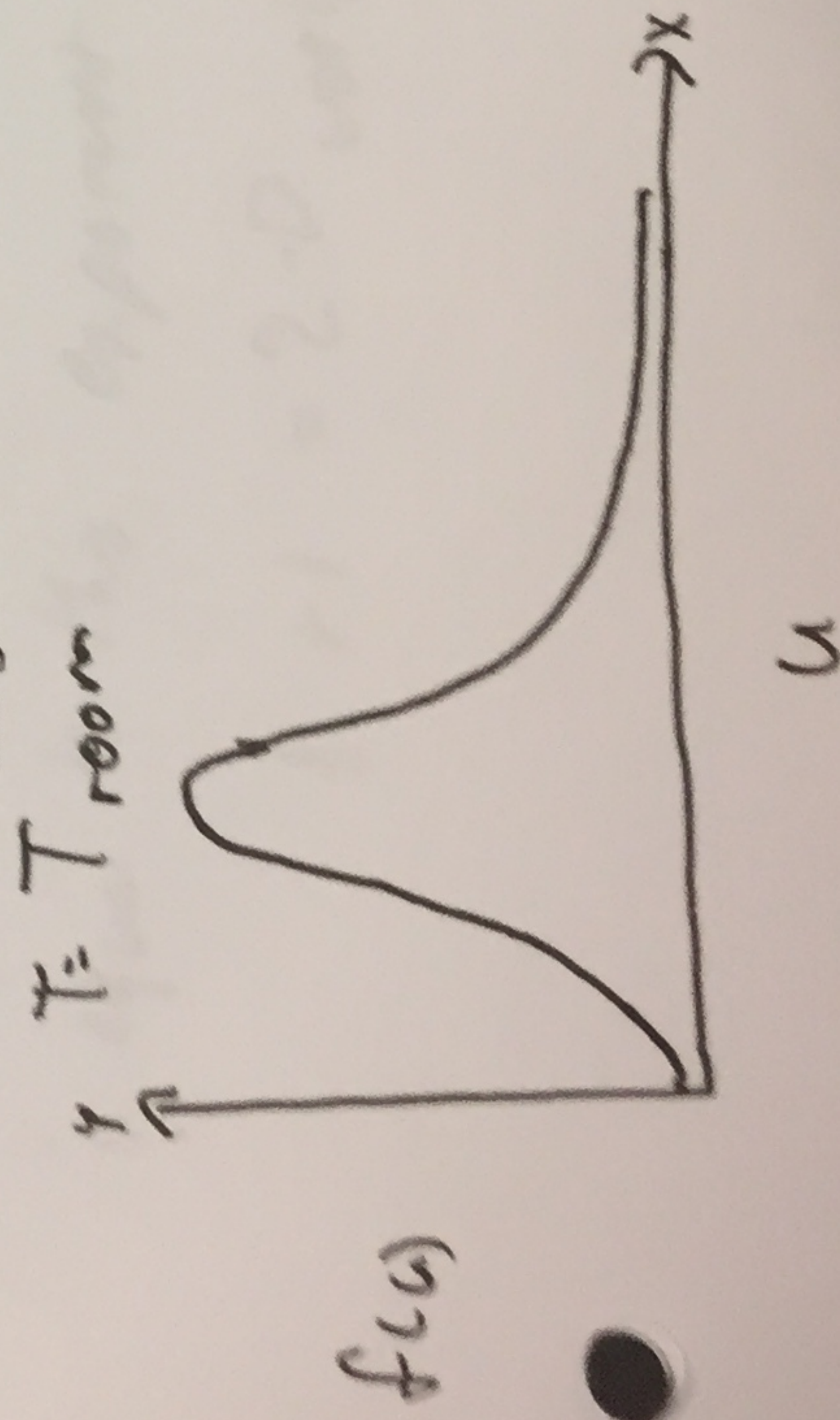
6. a. (5 points) Draw a graph showing the Maxwell Velocity Distribution.



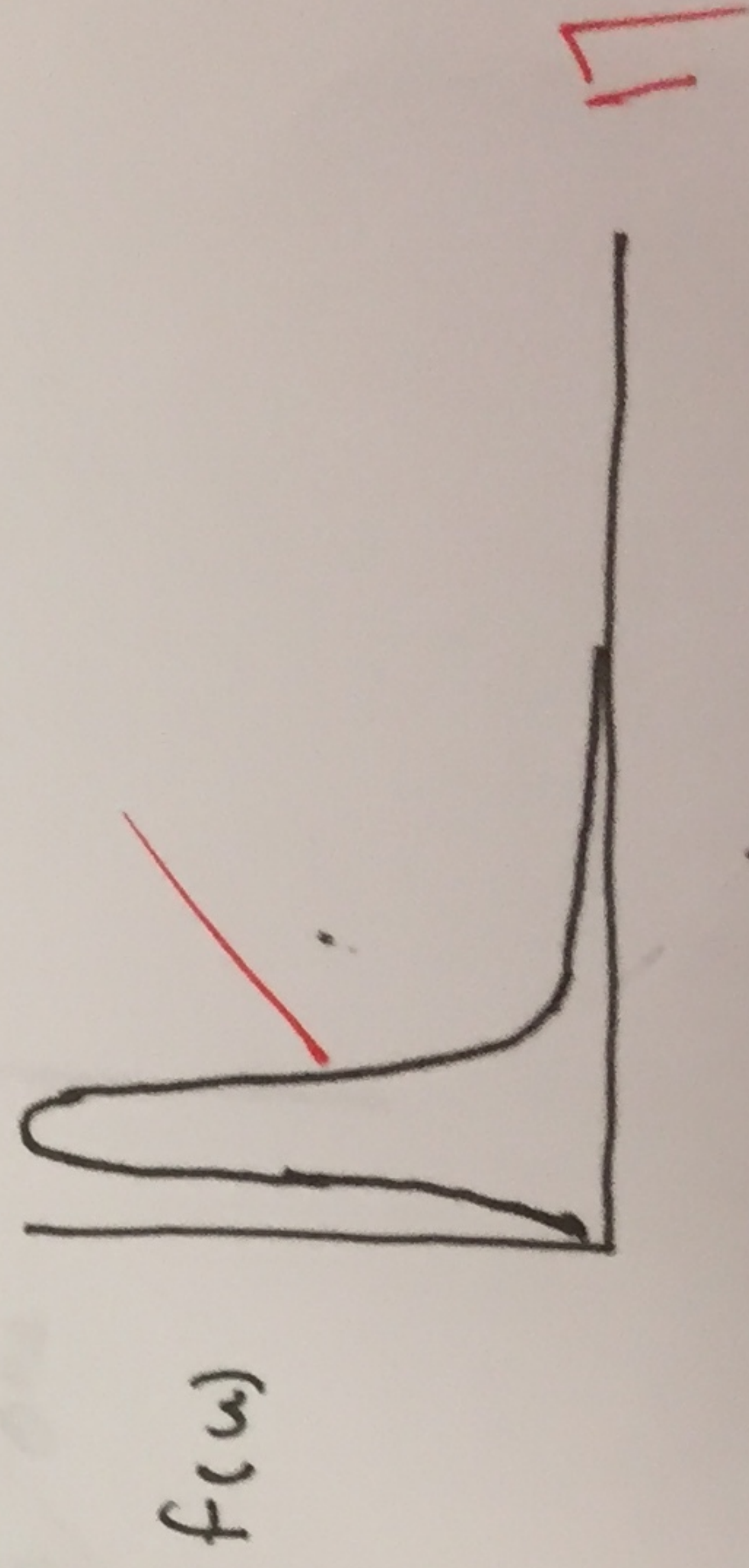
b. Label clearly on the graph the following:

- i) (4 points) Average velocity, u_{avg}
- ii) (4 points) Most prevalent velocity, u_{mp}

c. (4 points) Show graphically the changes that happen when the temperature of the gas is decreased from room temperature by about 100 K.



$T = 100\text{ K}$



11

The distribution is shifted to lower speeds and is more narrow.

Name Alex August-Schmidt

d. The Maxwell Distribution for a particular system in a different dimensional world (i.e., not our regular 3D world) is:

$$\frac{u^{2-1}}{\left(\sqrt{\frac{RT}{M}}\right)^b} \exp\left(\frac{-Mu^2}{2RT}\right)$$

i. (4 points) Give the value of 'b' in the equation above.

'b' is equal to the number of spatial dimensions in a different world. On Earth, $b=3$ because we are living in 3 spatial dimensions (length, width, and height). Since the u in the numerator is to the power

ii. (4 points) Based on your answer to (i) above, what is the dimension of that world? Explain.

The world is two dimensional as determined by the exponent of u in the numerator of the first term. The number of dimensions is equal to this exponent plus one.

$$1 + 1 = 2\text{-D world.}$$

Can tell that the world is two-dimensional. We know this because the exponent of the u term is the number of dimensions minus one. Thus we can tell that $b=2$.

Possibly useful information

Van der Waals equation: $p = \frac{nRT}{V-nb} - a\frac{n^2}{V^2}$

Isothermal compressibility: $\kappa \equiv -\frac{1}{V} \frac{\partial V}{\partial p} \Big|_T$

Thermal expansion coefficient: $\alpha \equiv \frac{1}{V} \frac{\partial V}{\partial T} \Big|_p$

Molarity: moles solute per liter solution

Molality: moles solute per kilogram solvent

$$\int x^n dx = \frac{x^{n+1}}{n+1} + c, \quad n \neq -1$$

$$\int \frac{1}{x-a} dx = \ln(x-a) + c$$

$$\frac{\partial y}{\partial x} = \frac{1}{\frac{\partial x}{\partial y}}$$

$$R \approx -8.31 \frac{\text{J}}{\text{K mol}} = 0.082 \frac{\text{L atm}}{\text{mol K}}$$

$$1 \text{ atm} \approx 1 \text{ bar} = 10\,000 \frac{\text{J}}{\text{m}^3} = 100 \frac{\text{J}}{\text{L}}$$

$$h = 6.626 \times 10^{-34} \text{ J s}$$

$$k_B = 1.308 \times 10^{-23} \frac{\text{J}}{\text{K}}$$