$2.25 \text{ mol} \times \frac{86.91 \text{ g}}{1 \text{ mol}} = 195.5 \text{ g}$

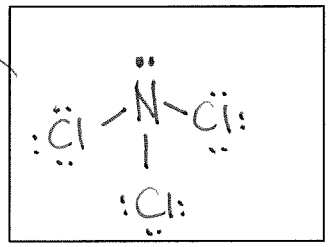
a 15. How many grams of OCl_2 are there in 2.25 mol OCl_2?
(a) 196 g (b) 38.6 g (c) 0.0259 g (d) 116 g

II. DRAWING AND DISCUSSION (40 points)

1. Draw the best Lewis structure (use formal charges if needed) of each the following molecules inside the box and complete the information below each box. Use the handout on molecular geometry provided to you. (21 points)

5 + 21 = 26 e (13 pr.)

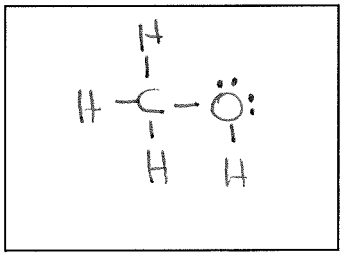
(a) **NCl_3**



ΔEN = 0.12 nonpolar

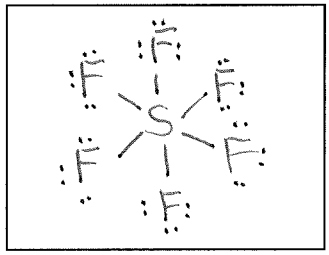
ΔEN > 0.4 & unsym.

(b) **CH_3OH**



ΔEN > 0.4 but symmetrical ⇓ nonpolar

(c) **SF_6**

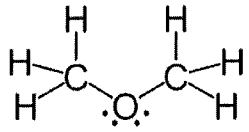


	(a) NCl_3	(b) CH_3OH	(c) SF_6
Polar or nonpolar?	Nonpolar	Polar	Nonpolar
Molecular geometry around the central atom	Trigonal pyramidal	Tetrahedral (4 bonds around C)	Octahedral
Indicate specific IMF in the liquid state	LDF	H-bonding	LDF

2. The following molecules have very similar molecular size. Arrange them in the order of increasing boiling point. Explain your answer. (4 points)

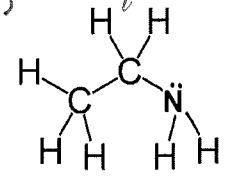
low to high

Propane, dimethyl ether, ethylamine



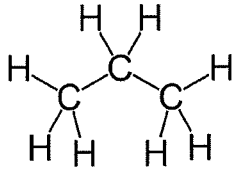
Dimethyl ether

Polar = dipole-dipole IMF



Ethylamine

H-bonding IMF



Propane

Nonpolar = LDF IMF

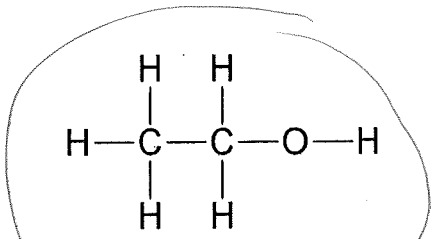
Boiling point increases with increasing strength of intermolecular forces of attraction. Since ethylamine exhibits H-bonding, the strongest of the three IMFs indicated above, it takes more heat to boil, hence highest boiling point.

3. Circle the molecule in each pair that is expected to have a *higher boiling point*. Explain your answer using specific IMFs that exist in each molecule and their relative strength. (7 pts.)

(a) NH_3 or PH_3

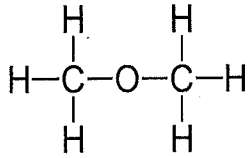
NH_3 is polar and exhibits H-bonding which is a much stronger IMF than the LDF exhibited by the nonpolar PH_3. Stronger IMF leads to higher boiling point.

(b)



Ethyl alcohol

or



Dimethyl ether

Ethyl alcohol exhibits H-bonding in solution, which is stronger than dipole-dipole exhibited by dimethyl ether, hence higher b.p. than the latter.

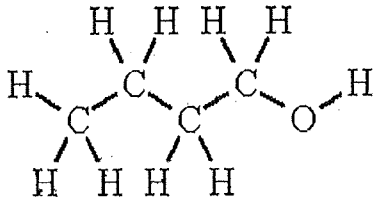
4. Circle the molecule in each pair that will exhibit a higher vapor pressure. Explain your answer using specific IMFs that exist in each molecule and their relative strength. (8 pts.)

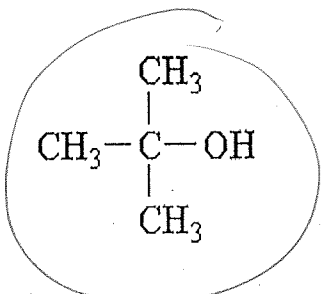
↳ easily vaporizes

(a) CCl_4 or CBr_4

Both are nonpolar, so the lighter (CCl_4) of the two will exhibit weaker London dispersion forces, thus vaporizing more easily and showing higher vapor pressure.

(b) *n*-butyl alcohol, $C_4H_{10}O$ or *tert*-butyl alcohol, $C_4H_{10}O$





These two have the same size and IMF, as they both exhibit H-bonding. However, the more linear n-butyl alcohol will have stronger surface-to-surface interactions than the "rounder" tert-butyl, which leads to stronger IMF + lower v.p. than tert-butyl.

III. BALANCING EQUATIONS and PROBLEM SOLVING (Stoichiometry) [30 points]

1. Balance the following equations. You do not have to show your work, but make sure your atom inventory matches! (10 points)

(a) $6\,K + B_2O_3 \rightarrow K_2O + 2\,B$ $\Rightarrow$ $6\,K + B_2O_3 \rightarrow 3\,K_2O + 2\,B$

2 B, 3 O. So balance the right side by tripling O + doubling B. Finally, balance K.

(b) $CCl_4 + HF \rightarrow CCl_2F_2 + HCl$

2 F & 2+1 = 3 Cl so need to double HCl, then balance HF on other side

$CCl_4 + 2\,HF \rightarrow CCl_2F_2 + 2\,HCl$

(c) $2\,SO_2 + O_2 + 2\,H_2O \rightarrow 2\,H_2SO_4$

2 S	2 S
4 + 2 + 2 = 8 O	8 O
4 H	4 H

(d) $3\,CaF_2 + 2\,Na_3PO_4 \rightarrow Ca_3(PO_4)_2 + 6\,NaF$

2 (PO_4)	2 (PO_4)
6 Na	6 N
6 F	6 F
3 Ca	3 Ca

OVER ⟶

III. PROBLEM SOLVING (Stoichiometry) – *Cont.*

INSTRUCTIONS:

- In order to get maximum credit you must show **ALL** your **work**, including **correct units** and **significant figures** for problems 2 and 3 below
- Please **circle** your final answer.
- Use the periodic table provided to you for atomic masses.

2. A 10.00 g sample of ammonia, NH_3 (MM 17.031 g/mol), is mixed with 30.00 g of oxygen, O_2 (MM 32.00 g/mol).

reactant 1 ↙ ↙ reactant 2

$$4\,NH_3\,(g) + 5\,O_2\,(g) \rightarrow 4\,NO\,(g) + 6\,H_2O\,(g)$$

↙ one of 2 products

Which is the limiting reactant? Calculate the maximum amount in grams of nitric oxide, NO (MM 30.01 g/mol) that can be formed from the given amounts of reactants. This is your theoretical yield. [15 points]

WORK:

Yield from NH_3:

$$10.00\ g\ NH_3 \times \frac{1\ mol\ NH_3}{17.031\ g\ NH_3} \times \frac{4\ mol\ NO}{4\ mol\ NH_3} \times \frac{30.01\ g\ NO}{1\ mol\ NO} = 17.62\ g\ NO\ *$$

(4 mol NO / 4 mol NH_3: from the balanced equation)

Yield from O_2:

$$30.00\ g\ O_2 \times \frac{1\ mol\ O_2}{32.00\ g\ O_2} \times \frac{4\ mol\ NO}{5\ mol\ O_2} \times \frac{30.01\ g\ NO}{1\ mol\ NO} = 22.51\ g\ NO$$

(4 mol NO / 5 mol O_2: from the balanced eqn)

* The lowest of the two yields is the theoretical yield and it comes from the limiting reactant.

Answer: Limiting reactant = NH_3 Theoretical yield = 17.62 g NO

3. Assuming that the reaction in #2 is carried out in the lab and the amount of NO produced was determined to be 12.67 g, what is the percent yield of NO? [5 points]

WORK:

$$\%\ yield = \frac{actual\ yield\ (= from\ the\ lab)}{theoretical\ yield} \times 100$$

$$= \frac{12.67\ g}{17.62\ g} \times 100 = 71.91\%$$

Answer: % yield = 71.91%