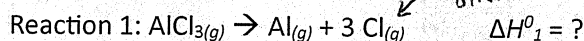


2. In the gas phase, AlCl_3 is a molecular substance. A reaction of gaseous AlCl_3 at high temperature is represented by the following balanced equation:



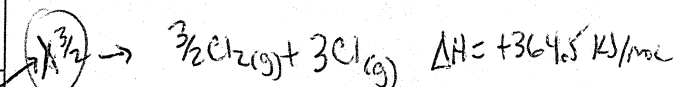
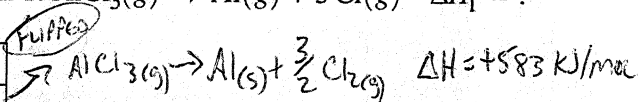
a) How many grams of $\text{Cl}(\text{g})$ can be formed from 1.25 mol of $\text{AlCl}_3(\text{g})$?

1.25 mol AlCl_3 $\times \frac{3 \text{ mol Cl}}{1 \text{ mol AlCl}_3} = 3.75 \text{ mol Cl}$
 $3.75 \text{ mol Cl} \times 35.45 \text{ g/mol} = 133. \text{ g Cl}$

Additional reactions that involve Al or Cl are shown in the following table.

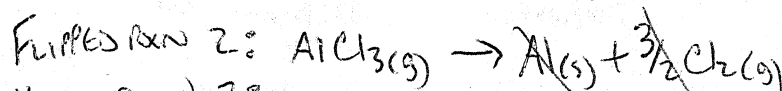


Reaction Number	Equation	$\Delta H^\circ_{\text{rxn}}$ (kJ/mol _{rxn})
2	$\text{Al}(\text{s}) + \frac{3}{2} \text{Cl}_2(\text{g}) \rightarrow \text{AlCl}_3(\text{g})$	-583
3	$\text{Al}(\text{s}) \rightarrow \text{Al}(\text{g})$	+326
4	$\text{Cl}_2(\text{g}) \rightarrow 2 \text{Cl}(\text{g})$	+243



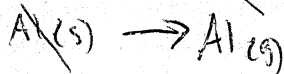
Hess's Law

b) Calculate the value of ΔH°_1 , in kJ/mol_{rxn}, for reaction 1 above using reactions 2, 3, and 4.



$\Delta H = +583 \text{ kJ/mol}$

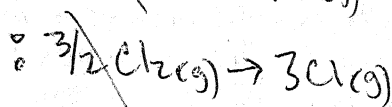
KEEP RXN 3:



$\Delta H = +326 \text{ kJ/mol}$

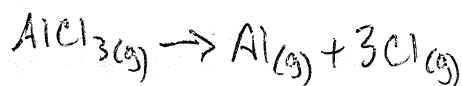
MULTIPLY RXN 4

BY $\frac{3}{2}$



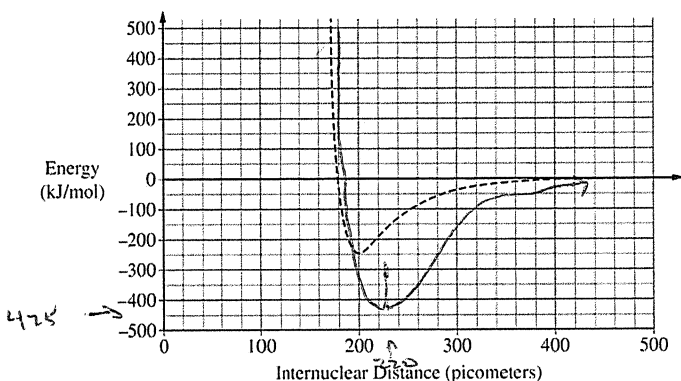
$\Delta H = +364.5 \text{ kJ/mol}$

1 PT



$\Delta H = +1274 \text{ kJ/mol}$

c) A potential energy diagram for Cl_2 is shown in the following graph.



BOND LENGTH = WHATEVER HAS LOWEST POTENTIAL ENERGY

(i) Based on the graph, what is the bond length, in picometers, for Cl_2 ?

1 PT

200 pm

(ii) A student finds that the average Al – Cl bond length is 220 picometers and the average bond energy is 425 kJ/mol. Draw the potential energy curve for the average Al – Cl bond on the preceding graph.

1 PT

Above

d) Three proposed Lewis diagrams for the $\text{AlCl}_3(\text{g})$ molecule are shown.

Al $\rightarrow 7e^-$
 $\times 3$
 $= 21e^-$
 $+ \text{Al} \rightarrow 3e^-$
 $\hline 24e^- \text{ TOTAL}$

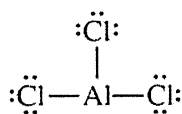


Diagram 1



Diagram 2

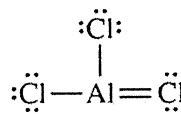


Diagram 3

(i) The $\text{AlCl}_3(\text{g})$ molecule has a trigonal planar geometry. Which diagram (1, 2, or 3) can be eliminated based on geometry? Justify your choice based on VSEPR theory.

DIAGRAM 2 CAN BE ELIMINATED, BECAUSE ITS GEOMETRY AS DRAWN WOULD BE TRIGONAL PYRAMIDAL. ALSO, DIAGRAM 3 IS INCORRECT BECAUSE IT HAS THE WRONG NUMBER OF ELECTRON DOTS, REPRESENTING 26 TOTAL VALENCE e^- INSTEAD OF 24.

1 PT

(ii) Which of the three diagrams is the best representation for the bonding in AlCl_3 ?

Justify your choice based on formal charges.

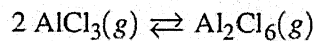
DIAGRAM 1 IS THE BEST CHOICE, FOR THE IDEAL FORMAL CHARGE FOR ALL ATOMS IN A MOLECULE IS ZERO, AS IT IS IN DIAGRAM 1. DIAGRAM 3 SHOWS A FORMAL CHARGE OF -1 FOR AL AND A +1 FORMAL CHARGE ON THE RIGHTMOST CL.

1 PT

Al: 3 VALENCE e^- , THEN SUBTRACT OFF 4 BONDS (BECAUSE DOUBLE BOND COUNTS TWICE FOR FORMAL CHARGE) FOR A -1 CHARGE.

Cl: Cl^{+7} , THEN ADD 2 ^{BONDS} FOR FORMAL CHARGE OF +1 + 4 FROM UNSHARED

AlCl_3 is known to dimerize reversibly in the gas phase. The dimerization equilibrium is represented by the following equation.

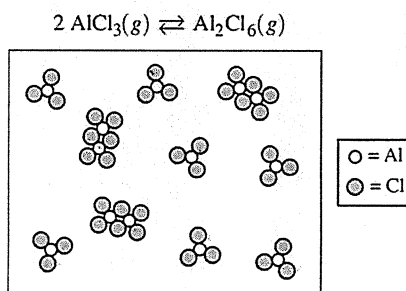


e) Write the expression for the equilibrium constant, K_p , for this reaction.

$$K_p = \frac{(P_{\text{Al}_2\text{Cl}_6})}{(P_{\text{AlCl}_3})^2}$$

1 PT

A particle-level diagram of an equilibrium mixture of $\text{AlCl}_3(g)$ and $\text{Al}_2\text{Cl}_6(g)$ at 400°C in a 25 L closed container is shown.



f) Using the particle-level diagram, calculate the K_p for the reaction if the total pressure in the container is 22.1 atm.

$$P_{\text{AlCl}_3} = \frac{7}{10} \times 22.1 \text{ atm} = 15.5 \text{ atm AlCl}_3$$

1 PT

$$P_{\text{Al}_2\text{Cl}_6} = \frac{3}{10} \times 22.1 \text{ atm} = 6.63 \text{ atm Al}_2\text{Cl}_6$$

1 PT

$$K_p = \frac{(P_{\text{Al}_2\text{Cl}_6})}{(P_{\text{AlCl}_3})^2} = \frac{(6.63)}{(15.5)^2} = 0.0276$$