Begin your response to **QUESTION 2** on this page.

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.

$$\text{Reaction 1: } AlCl_3(g) \rightarrow Al(g) + 3\,Cl(g) \quad \Delta H_1^\circ = ?$$

(a) How many grams of $Cl(g)$ can be formed from $1.25\ \text{mol}$ of $AlCl_3(g)$?

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

Reaction Number	Equation	ΔH_{rxn}° (kJ/mol_{rxn})
2	$Al(s) + \frac{3}{2}\,Cl_2(g) \rightarrow AlCl_3(g)$	-583
3	$Al(s) \rightarrow Al(g)$	$+326$
4	$Cl_2(g) \rightarrow 2\,Cl(g)$	$+243$

(b) Calculate the value of ΔH_1°, in kJ/mol_{rxn}, for reaction 1 above using reactions 2, 3, and 4.

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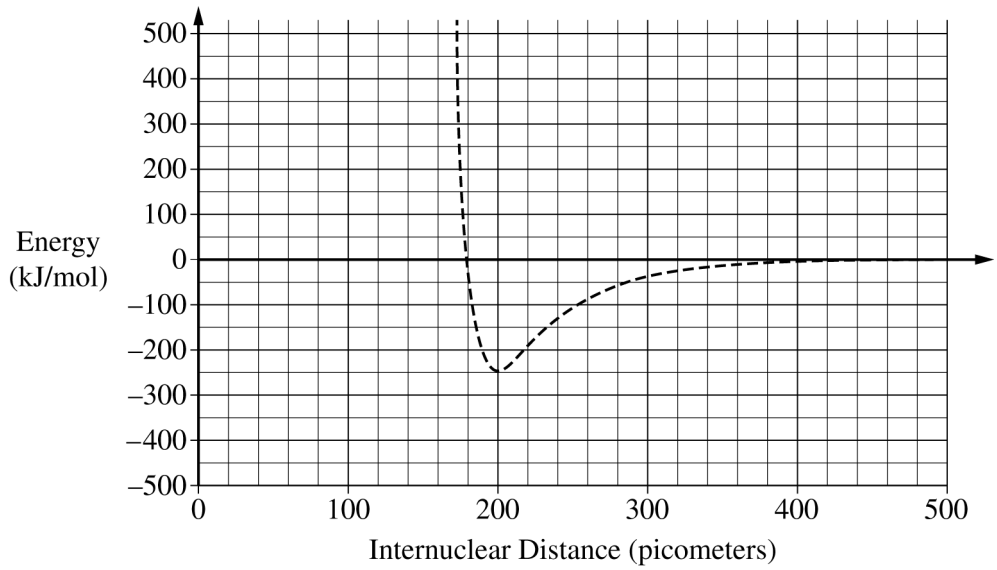
Continue your response to **QUESTION 2** on this page.

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



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

(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.

(d) Three proposed Lewis diagrams for the $AlCl_3(g)$ molecule are shown.

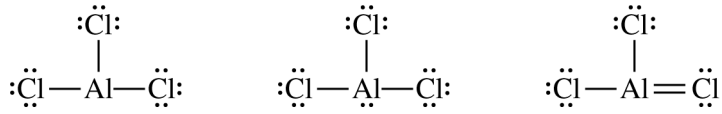


Diagram 1 Diagram 2 Diagram 3

(i) The $AlCl_3(g)$ 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.

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Continue your response to **QUESTION 2** on this page.

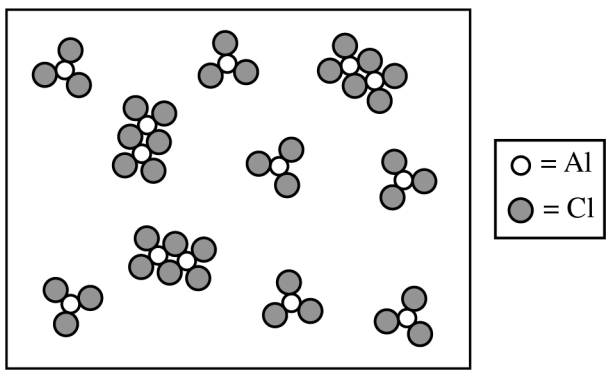
(ii) Which of the three diagrams is the best representation for the bonding in $AlCl_3$? Justify your choice based on formal charges.

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

$$2\ AlCl_3(g) \rightleftarrows Al_2Cl_6(g)$$

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

A particle-level diagram of an equilibrium mixture of $AlCl_3(g)$ and $Al_2Cl_6(g)$ at 400°C in a 25 L closed container is shown.



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

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Question 2: Long Answer — 10 points

(a) For the correct calculated value reported with the correct number of significant figures: **1 point**

$$1.25 \text{ mol } AlCl_3 \times \frac{3 \text{ mol Cl}}{1 \text{ mol } AlCl_3} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}} = 133 \text{ g Cl}$$

(b) For the correct algebraic manipulation of either ΔH_2° or ΔH_4° (may be implicit): **1 point**

Accept one of the following:

- *Reversing reaction 2:*
  $AlCl_3(g) \rightarrow Al(s) + \frac{3}{2}Cl_2(g) \quad \Delta H_{rxn}^\circ = -(-583) = +583 \text{ kJ/mol}_{rxn}$
- *Multiplying reaction 4 by* $\frac{3}{2}$*:*
  $\frac{3}{2}(Cl_2(g) \rightarrow 2\,Cl(g)) \quad \Delta H_{rxn}^\circ = \frac{3}{2}(+243) = +365 \text{ kJ/mol}_{rxn}$

For the correct calculated value: **1 point**

$$\Delta H_1^\circ = -\Delta H_2^\circ + \Delta H_3^\circ + 1.5(\Delta H_4^\circ) = -(-583) + 326 + 1.5(243) = 1274 \text{ kJ/mol}_{rxn}$$

Total for part (b) 2 points

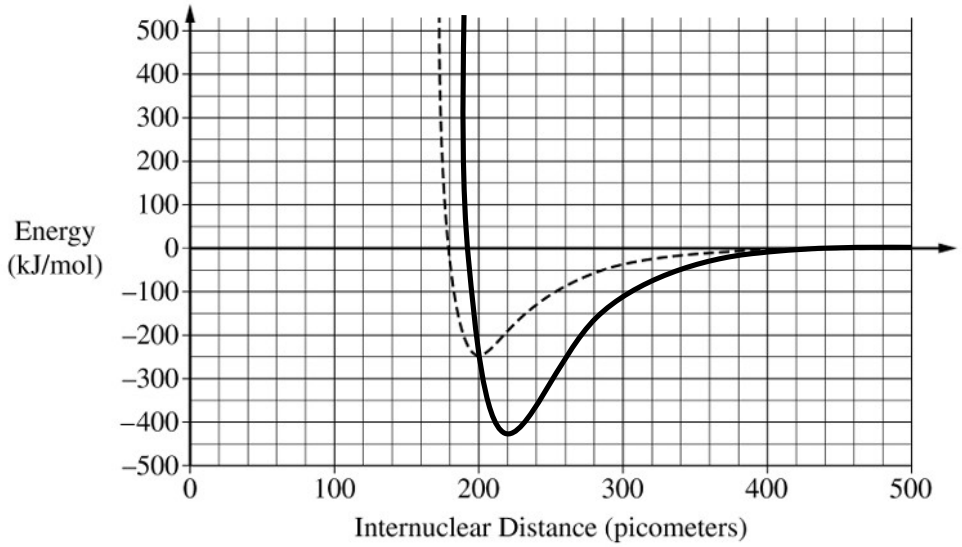
(c) (i) For the correct answer: **1 point**

200 picometers (±10 pm)

(ii) For a curve with a minimum at an internuclear distance of 220 ± 10 pm: **1 point**

See sample curve below

For a curve with a minimum energy value of -425 ± 20 kJ/mol that approaches zero as the internuclear distance approaches 500 pm: **1 point**



Total for part (c) 3 points

(d) (i)	For the correct answer and a valid justification: *Diagram 2. Al has four electron domains in Diagram 2, which would be trigonal pyramidal, not trigonal planar.*	**1 point**
(ii)	For the correct answer and a valid justification: *Diagram 1. All atoms in diagram 1 have a formal charge of zero, whereas atoms in diagrams 2 and 3 have nonzero formal charges.*	**1 point**
	Total for part (d)	**2 points**
(e)	For the correct answer: $K_p = \frac{P_{Al_2Cl_6}}{(P_{AlCl_3})^2}$	**1 point**
(f)	For the correct calculated value, consistent with part (e): $K_p = \frac{\chi_{Al_2Cl_6}(P_{total})}{\left(\chi_{AlCl_3}(P_{total})\right)^2} = \frac{\frac{3}{10}(22.1)}{\left(\frac{7}{10}(22.1)\right)^2} = 0.0277$	**1 point**
	Total for question 2	**10 points**