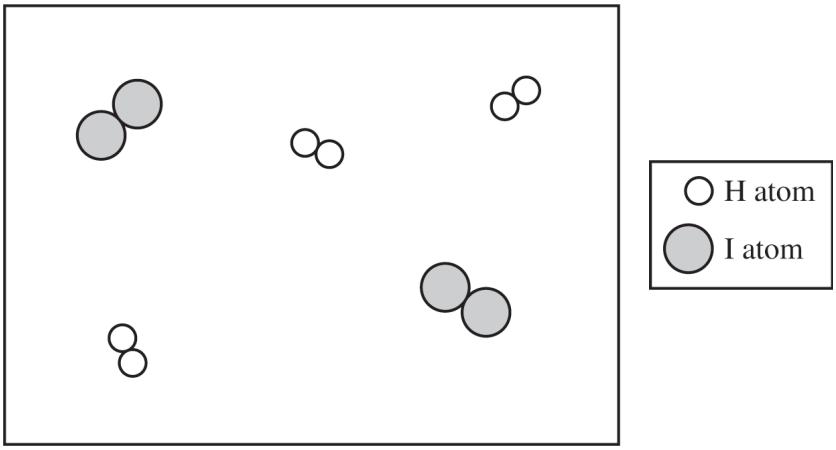
5. Hydrogen gas and iodine gas react to form hydrogen iodide at an elevated temperature, as represented by the following equation.

$$H_2(g) + I_2(g) \rightleftarrows 2\,HI(g) \qquad \Delta H_{rxn} = -12.19\ \text{kJ / mol}_{rxn}$$

(a) Write the expression for the equilibrium constant, K_c, for this reaction.

(b) $H_2(g)$ and $I_2(g)$ are added to a previously evacuated container and allowed to react.

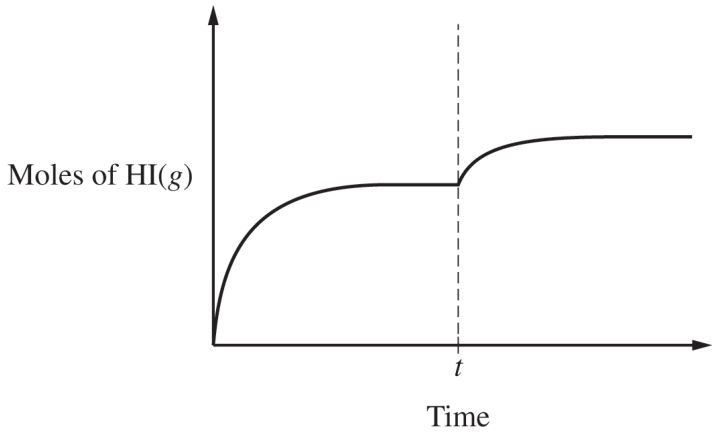
(i) At a certain time, the value of the reaction quotient, Q, is 0.67. The following particle diagram is an incomplete representation of the system at this time. The diagram shows the relative number of $H_2(g)$ and $I_2(g)$ molecules, but the $HI(g)$ molecules are not included. Draw the number of $HI(g)$ molecules needed to complete the diagram so that it accurately represents the system.



GO ON TO THE NEXT PAGE.

Continue your response to **QUESTION 5** on this page.

(ii) A student monitors the number of moles of $HI(g)$ over time. Hypothesize an experimental change that could have been applied to the system in the rigid container at time t to result in the change in the number of moles of $HI(g)$ shown in the graph. Assume that the student did not add more $HI(g)$ to the system.



(iii) After equilibrium is established, the mixture is transferred to a larger container at constant temperature. As a result, would the number of moles of $HI(g)$ increase, decrease, or remain the same? Justify your answer.

GO ON TO THE NEXT 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.

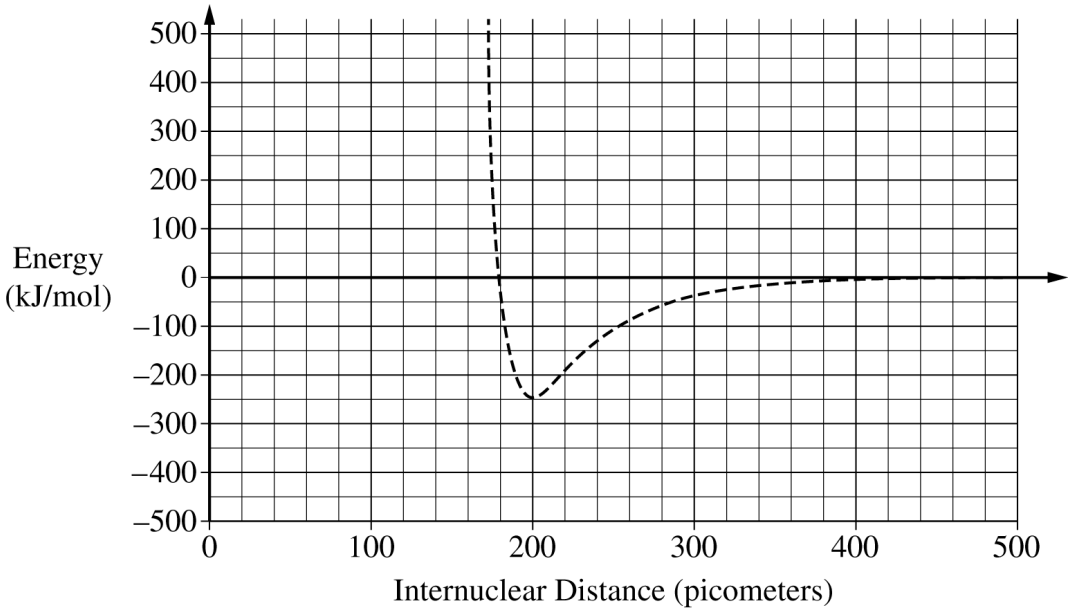
Reaction Number	Equation	ΔH_{rxn}° (kJ/mol_{rxn})
2	$Al(s) + \frac{3}{2}\,Cl_2(g) \rightarrow AlCl_3(g)$	-583
3	$Al(s) \rightarrow Al(g)$	$+326$
4	$Cl_2(g) \rightarrow 2\,Cl(g)$	$+243$

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

GO ON TO THE NEXT PAGE.

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.

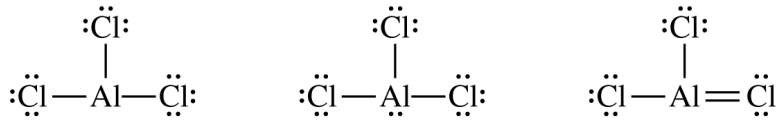


Diagram 1 Diagram 2 Diagram 3

(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.

GO ON TO THE NEXT PAGE.

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

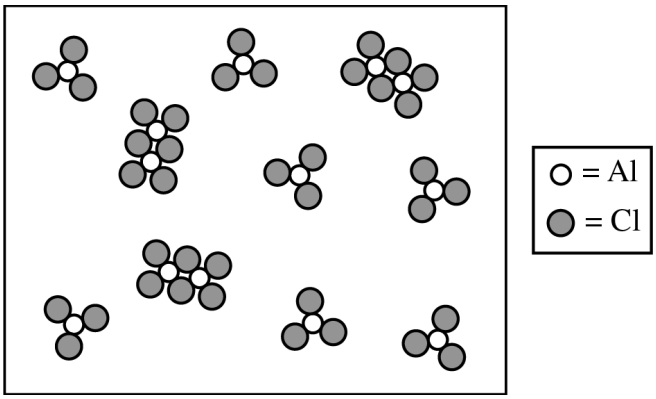
(ii) Which of the three diagrams is the best representation for the bonding in $AlCl_3$? Justify your choice based on formal charges.

$AlCl_3$ 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.

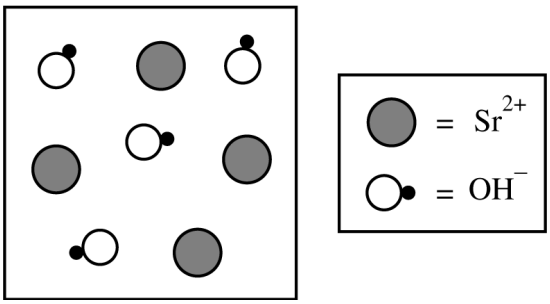


(f) Using the particle-level diagram, calculate the value of K_p for the reaction if the total pressure in the container is 22.1 atm.

GO ON TO THE NEXT PAGE.

. Strontium hydroxide dissolves in water according to the following equation. The K_{sp} expression for strontium hydroxide is provided.

$$Sr(OH)_2(s) \rightleftarrows Sr^{2+}(aq) + 2\,OH^-(aq) \qquad K_{sp} = [Sr^{2+}][OH^-]^2$$



(a) A student draws the particulate diagram shown to represent the ions present in an aqueous solution of $Sr(OH)_2$. (Water molecules are intentionally omitted.) Identify the error in the student's drawing.

(b) The student prepares a saturated solution by adding excess $Sr(OH)_2(s)$ to distilled water and stirring until no more solid dissolves. The student then determines that $[Sr^{2+}] = 0.043\ M$ in the solution.

(i) Calculate the value of $[OH^-]$ in the solution.

(ii) Calculate the value of K_{sp} for $Sr(OH)_2$.

GO ON TO THE NEXT PAGE.

Continue your response to **QUESTION 7** on this page.

(c) The student prepares a second saturated solution of $Sr(OH)_2$ in aqueous 0.10 M $Sr(NO_3)_2$ instead of water. Will the value of $[OH^-]$ in the second solution be greater than, less than, or equal to the value in the first solution? Justify your answer. (Assume constant temperature.)

STOP

END OF EXAM