

## 2019 AP<sup>®</sup> CHEMISTRY FREE-RESPONSE QUESTIONS

2. Answer the following questions relating to the chemistry of the halogens.

- (a) The molecular formulas of diatomic bromine, chlorine, fluorine, and iodine are written below. Circle the formula of the molecule that has the longest bond length. Justify your choice in terms of atomic structure.



A chemistry teacher wants to prepare Br<sub>2</sub>. The teacher has access to the following three reagents: NaBr(aq), Cl<sub>2</sub>(g), and I<sub>2</sub>(s).

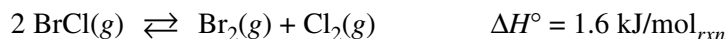
Half-Reaction	<i>E</i> <sup>°</sup> at 25°C (V)
Br <sub>2</sub> + 2 e <sup>-</sup> → 2 Br <sup>-</sup>	1.07
Cl <sub>2</sub> + 2 e <sup>-</sup> → 2 Cl <sup>-</sup>	1.36
I <sub>2</sub> + 2 e <sup>-</sup> → 2 I <sup>-</sup>	0.53

- (b) Using the data in the table above, write the balanced equation for the thermodynamically favorable reaction that will produce Br<sub>2</sub> when the teacher combines two of the reagents. Justify that the reaction is thermodynamically favorable by calculating the value of *E*<sup>°</sup> for the reaction.

Br<sub>2</sub> and Cl<sub>2</sub> can react to form the compound BrCl.

- (c) The boiling point of Br<sub>2</sub> is 332 K, whereas the boiling point of BrCl is 278 K. Explain this difference in boiling point in terms of all the intermolecular forces present between molecules of each substance.

The compound BrCl can decompose into Br<sub>2</sub> and Cl<sub>2</sub>, as represented by the balanced chemical equation below.



A 0.100 mole sample of pure BrCl(g) is placed in a previously evacuated, rigid 2.00 L container at 298 K. Eventually the system reaches equilibrium according to the equation above.

- (d) Calculate the pressure in the container before equilibrium is established.  
 (e) Write the expression for the equilibrium constant, *K*<sub>eq</sub>, for the decomposition of BrCl.

After the system has reached equilibrium, 42 percent of the original BrCl sample has decomposed.

- (f) Determine the value of *K*<sub>eq</sub> for the decomposition reaction of BrCl at 298 K.  
 (g) Calculate the bond energy of the Br-Cl bond, in kJ/mol, using Δ*H*<sup>°</sup> for the reaction (1.6 kJ/mol<sub>rxn</sub>) and the information in the following table.

Bond	Bond Energy (kJ/mol)
Br – Br	193
Cl – Cl	243
Br – Cl	?