ANSWER KEY.

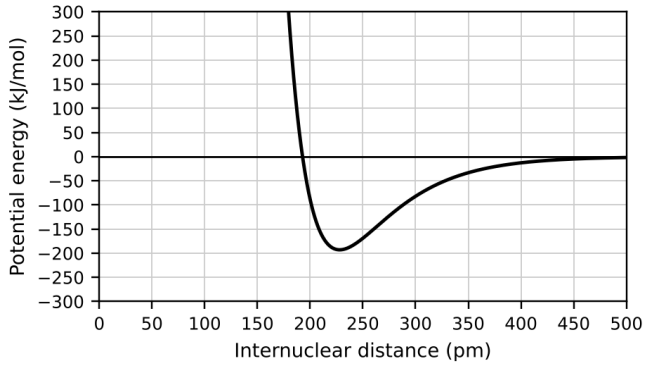
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2.2 Intramolecular Force and Potential Energy

AP Chemistry | ANSWER KEY

Read graphs carefully and include units. Show your setup for every calculation.

1. The graph shows the potential energy of two bromine atoms as a function of the distance between their nuclei.



(a) Estimate the bond length of Br_2.

(b) Estimate the bond energy of Br_2.

(c) Why is the potential energy close to zero when the atoms are 500 pm apart?

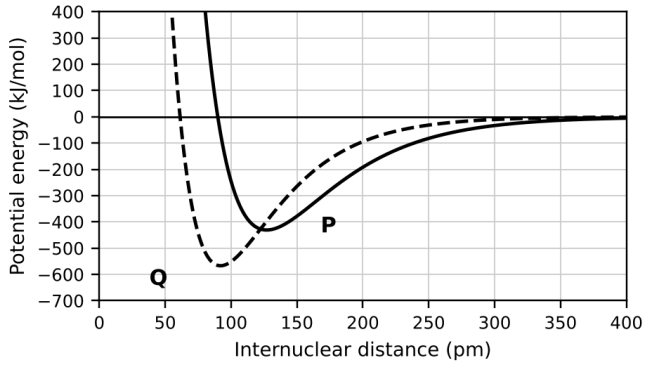
(d) Why does the potential energy rise sharply at distances shorter than the bond length?

(a) about 230 pm (accepted value 228 pm) (b) about 190 kJ/mol (accepted value 193 kJ/mol)

(c) The atoms are too far apart to interact, so there is no attraction or repulsion.

(d) The nuclei (and the electrons) get so close that repulsion is greater than attraction.

2. One curve below is for HF and the other is for HCl.



(a) Which curve represents HCl? Justify your answer using atomic size.

(b) Estimate the bond energy of the molecule shown by curve Q.

(a) Curve P. Cl is larger than F (it has an extra electron shell), so the H–Cl bond is longer (minimum farther right) and weaker (shallower well).

(b) about 570 kJ/mol (HF, accepted value 567 kJ/mol)

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3. The bond energies 305, 615, and 891 kJ/mol belong to the three carbon-nitrogen bonds below. Match each energy to its bond, then explain the pattern.

Bond	Bond length (pm)	Bond energy (kJ/mol)
C–N	147	**305**
C=N	127	**615**
C≡N	116	**891**

Higher bond order (more shared pairs) gives a shorter, stronger bond, so the triple bond has the greatest bond energy.

4. Use Coulomb's law to estimate how many times stronger the attraction between ions is in MgO than in LiF. Ionic radii: Li^{+} 76 pm, Mg^{2+} 72 pm, F^{-} 133 pm, O^{2-} 140 pm.

r(LiF) = 76 pm + 133 pm = 209 pm; r(MgO) = 72 pm + 140 pm = 212 pm

$F(MgO) / F(LiF) = [(2)(2) / (212\ pm)^2] / [(1)(1) / (209\ pm)^2] = 4 \times (209/212)^2 = 3.89$

The attraction in MgO is about 3.9 times stronger. The larger charges matter most; the distances are almost the same.

5. Rank NaF, NaCl, and KCl from **highest** to **lowest** melting point. Justify your ranking with Coulomb's law. Radii: Na^{+} 102 pm, K^{+} 138 pm, F^{-} 133 pm, Cl^{-} 181 pm.

r: NaF = 235 pm, NaCl = 283 pm, KCl = 319 pm. All three have charges of 1+ and 1−.

NaF > NaCl > KCl. With the same charges, a smaller distance gives a stronger attraction, which takes more energy to overcome. (Actual: 993 °C, 801 °C, 770 °C)

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