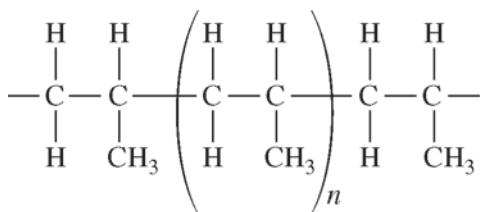
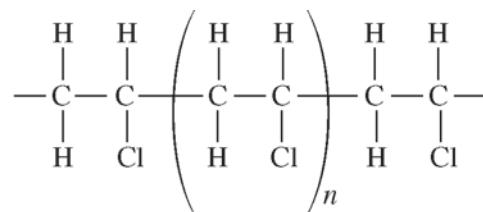


2014 AP[®] CHEMISTRY FREE-RESPONSE QUESTIONS

6. A student places a mixture of plastic beads consisting of polypropylene (PP) and polyvinyl chloride (PVC) in a 1.0 L beaker containing distilled water. After stirring the contents of the beaker vigorously, the student observes that the beads of one type of plastic sink to the bottom of the beaker and the beads of the other type of plastic float on the water. The chemical structures of PP and PVC are represented by the diagrams below, which show segments of each polymer.



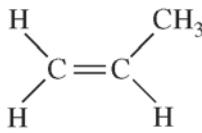
PP



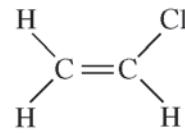
PVC

- (a) Given that the spacing between polymer chains in PP and PVC is similar, the beads that sink are made of which polymer? Explain.

PP is synthesized from propene, C₃H₆, and PVC is synthesized from vinyl chloride, C₂H₃Cl. The structures of the molecules are shown below.



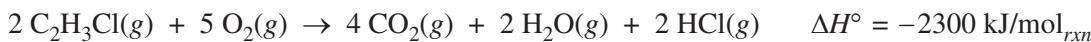
Propene



Vinyl Chloride (chloroethene)

- (b) The boiling point of liquid propene (226 K) is lower than the boiling point of liquid vinyl chloride (260 K). Account for this difference in terms of the types and strengths of intermolecular forces present in each liquid.

In a separate experiment, the student measures the enthalpies of combustion of propene and vinyl chloride. The student determines that the combustion of 2.00 mol of vinyl chloride releases 2300 kJ of energy, according to the equation below.



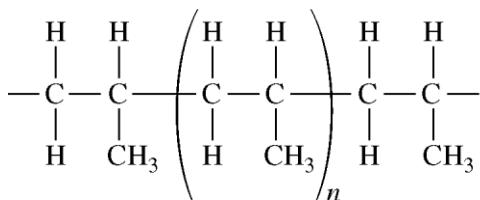
- (c) Using the table of standard enthalpies of formation below, determine whether the combustion of 2.00 mol of propene releases more, less, or the same amount of energy that 2.00 mol of vinyl chloride releases. Justify your answer with a calculation. The balanced equation for the combustion of 2.00 mol of propene is 2 C₃H₆(g) + 9 O₂(g) → 6 CO₂(g) + 6 H₂O(g).

Substance	C ₂ H ₃ Cl(g)	C ₃ H ₆ (g)	CO ₂ (g)	H ₂ O(g)	HCl(g)	O ₂ (g)
Standard Enthalpy of Formation (kJ/mol)	37	21	-394	-242	-92	0

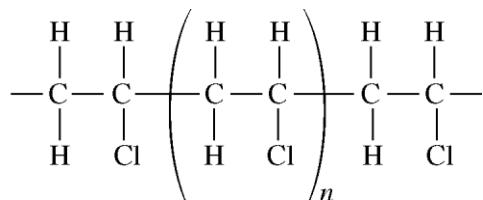
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2014 SCORING GUIDELINES**

**Question 6
(4 points)**

A student places a mixture of plastic beads consisting of polypropylene (PP) and polyvinyl chloride (PVC) in a 1.0 L beaker containing distilled water. After stirring the contents of the beaker vigorously, the student observes that the beads of one type of plastic sink to the bottom of the beaker and the beads of the other type of plastic float on the water. The chemical structures of PP and PVC are represented by the diagrams below, which show segments of each polymer.



PP

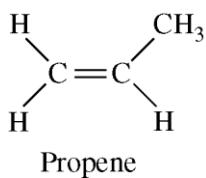


PVC

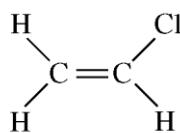
- (a) Given that the spacing between polymer chains in PP and PVC is similar, the beads that sink are made of which polymer? Explain.

<p>The PVC beads sink. The spacing between chains is similar, but a Cl atom has a greater mass than CH₃.</p>	<p>1 point is earned for the correct polymer with a correct explanation.</p>
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PP is synthesized from propene, C₃H₆, and PVC is synthesized from vinyl chloride, C₂H₃Cl. The structures of the molecules are shown below.



Propene



Vinyl Chloride (chloroethene)

- (b) The boiling point of liquid propene (226 K) is lower than the boiling point of liquid vinyl chloride (260 K). Account for this difference in terms of the types and strengths of intermolecular forces present in each liquid.

<p>Both substances have dipole-dipole interactions and London dispersion forces (or propene is essentially nonpolar with only LDFs while vinyl chloride has both LDFs and dipole-dipole forces). Propene contains a CH₃ group, but vinyl chloride contains a Cl atom. Vinyl chloride thus has a larger electron cloud, is more polarizable, and has a larger dipole moment. Thus intermolecular attractions are stronger in vinyl chloride, which results in it having the higher boiling point.</p>	<p>1 point is earned for a discussion of intermolecular forces and for a comparison of their relative strengths.</p>
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Question 6 (continued)

In a separate experiment, the student measures the enthalpies of combustion of propene and vinyl chloride. The student determines that the combustion of 2.00 mol of vinyl chloride releases 2300 kJ of energy, according to the equation below.



- (c) Using the table of standard enthalpies of formation below, determine whether the combustion of 2.00 mol of propene releases more, less, or the same amount of energy that 2.00 mol of vinyl chloride releases. Justify your answer with a calculation. The balanced equation for the combustion of 2.00 mol of propene is $2 \text{C}_3\text{H}_6(g) + 9 \text{O}_2(g) \rightarrow 6 \text{CO}_2(g) + 6 \text{H}_2\text{O}(g)$.

Substance	$\text{C}_2\text{H}_3\text{Cl}(g)$	$\text{C}_3\text{H}_6(g)$	$\text{CO}_2(g)$	$\text{H}_2\text{O}(g)$	$\text{HCl}(g)$	$\text{O}_2(g)$
Standard Enthalpy of Formation (kJ/mol)	37	21	-394	-242	-92	0

$\Delta H^\circ = 6(-394) + 6(-242) - 2(21) = -3858 \text{ kJ/mol}_{rxn}$ <p>The combustion of 2.00 mol of propene releases more energy.</p>	1 point is earned for the calculation of the enthalpy of combustion of propene. 1 point is earned for the comparison of propene to vinyl chloride that is consistent with the calculated value.
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