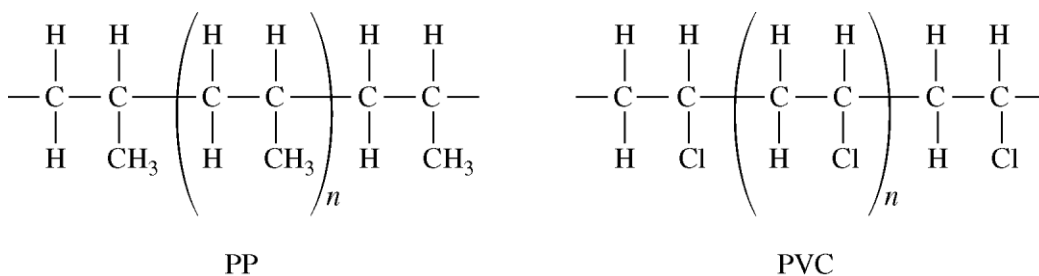


AP[®] CHEMISTRY
2014 SCORING GUIDELINES

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.



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

The PVC beads sink. The spacing between chains is similar, but a Cl atom has a greater mass than CH ₃ .	1 point is earned for the correct polymer with a correct explanation.
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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.



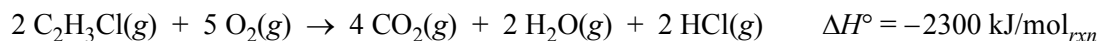
- (b) The boiling point of liquid propene (226 K) is lower than the boiling point of liquid vinyl chloride (260 K). Account for this difference in terms of the types and strengths of intermolecular forces present in each liquid.

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 CH ₃ 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.	1 point is earned for a discussion of intermolecular forces <u>and</u> for a comparison of their relative strengths.
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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 $2 \text{C}_3\text{H}_6(g) + 9 \text{O}_2(g) \rightarrow 6 \text{CO}_2(g) + 6 \text{H}_2\text{O}(g)$.

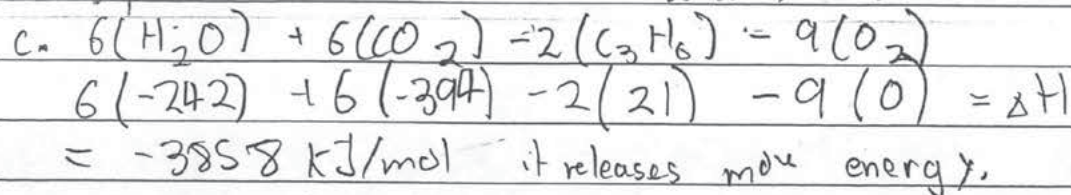
Substance	$\text{C}_2\text{H}_3\text{Cl}(g)$	$\text{C}_3\text{H}_6(g)$	$\text{CO}_2(g)$	$\text{H}_2\text{O}(g)$	$\text{HCl}(g)$	$\text{O}_2(g)$
Standard Enthalpy of Formation (kJ/mol)	37	21	-394	-242	-92	0

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

a. the beads that sink are made of PVC because it is more dense than PP because with the same spacing the Cl atom gives it much more mass per unit of volume

b. Vinyl Chloride is a polar molecule while propene is not so Vinyl Chloride has dipole-dipole forces of attraction and Propene only has induced dipole-induced dipole forces of attraction and dipole-dipole forces are stronger so they are harder to separate and harder for these substances to boil



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PAGE FOR ANSWERING QUESTION 6

a. The beads that sink are made of PVC because it has a higher molar mass than PP but equal spacing. Therefore it has a higher density and will sink.

b. Vinyl chloride is more polar than propane because the electronegative Cl atom creates stronger intermolecular forces. These forces take more energy to overcome for the molecule to become a gas, so the boiling point for Vinyl chloride is higher.

$$c. \Delta H^\circ = 2H^\circ_{\text{PVC}} + 2H^\circ_{\text{H}_2\text{O}} + 4H^\circ_{\text{CO}_2} - 5H^\circ_{\text{O}_2} - 2H^\circ_{\text{C}_2\text{H}_3\text{Cl}}$$

$$= 2(-92) + 2(-242) + 4(-394) - 5(0) - 2(37)$$

$$\Delta H^\circ = -2318 \text{ kJ/mol rxn}$$

$$\Delta H^\circ = 6H^\circ_{\text{H}_2\text{O}} + 6H^\circ_{\text{CO}_2} - 9H^\circ_{\text{O}_2} - 2H^\circ_{\text{C}_3\text{H}_8}$$

$$= 6(-242) + 6(-394) - 9(0) - 2(21)$$

$$\Delta H^\circ = -3858 \text{ kJ/mol rxn}$$

2 ml of propane releases ^{more} energy than
2 ml of vinyl chloride.

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a) PVC because it has Hydrogen-bonding

b) Vinyl chloride has H-bonds and so it takes more energy to separate the molecules.

$$\begin{aligned} \text{c) } \Delta H &= (6(-394) + 6(-242)) - (2(21) + 9(0)) \\ &= -3816 - 42 \\ &\approx -3858 \text{ kJ/mol}_{\text{rxn}} \quad \leftarrow \text{for propene} \end{aligned}$$

combustion of 2.00 mol propene releases more energy than combustion of 2.00 mol vinyl chloride because $3858 > 2300$, (negatives of Enthalpy is just that it is being released).

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AP[®] CHEMISTRY
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Question 6

Overview

This question integrated the concepts of physical properties of compounds and heats of reaction. Propene and the polymer polypropylene (PP), and chloroethane (vinyl chloride) and the polymer polyvinyl chloride (PVC) were compounds used in this question. Knowledge of the relationship of mass to volume (density) was needed to answer part (a) to determine which polymer would sink relative to water. For part (b) knowledge of differences in electronegativities, polar bonds, dipole moment, size of the electron cloud, and polarizability was needed to determine the intermolecular forces possible for a given molecule. Once the kinds of intermolecular forces were determined for each molecule, a comparison of relative strengths of those intermolecular forces was needed to explain the given differences in boiling points. Specifically students had to recognize the presence and strength of London dispersion forces and dipole-dipole forces of attraction in the two molecules given in order to explain the difference in boiling points. In part (c) the student needed to calculate the ΔH° for the combustion of 2 moles of propene and then compare that calculated value to the given ΔH° of vinyl chloride as being more, less, or the same.

Sample: 6A

Score: 4

This response earned all four possible points: 1 point in part (a), 1 point in part (b), and 2 points in part (c).

Sample: 6B

Score: 3

The point was not earned in part (b); vinyl chloride was identified as being the more polar molecule but the student never identifies the intermolecular forces present. Simply mentioning stronger intermolecular forces did not earn the point.

Sample: 6C

Score: 2

The point in part (a) was not earned because hydrogen bonding is not relevant to the sinking or floating of the polymers. The point was not earned in part (b) because hydrogen bonding is not relevant to this question.