

Enthalpy Costs Card Game

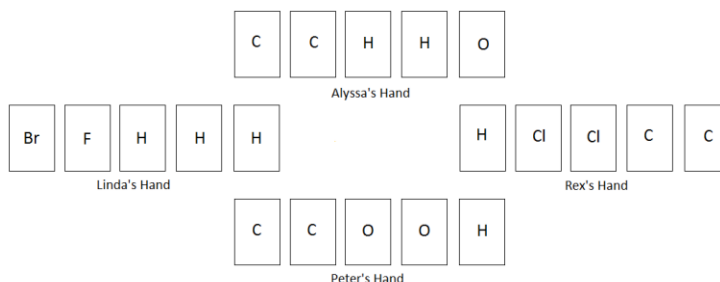


Rules and Scoring Guide

- Partners should sit across from one another at the game table.
- After shuffling the cards, each player draws a card and flips it over. The player holding the card with the highest atomic number becomes the dealer.
- After reshuffling, each player is dealt five cards and the remaining cards are placed in the middle of the table along with the lone pair electron cards and the bond sticks.
- The dealer becomes the first player and play proceeds in a clockwise direction.
- Starting each turn, the player's partner passes one of the cards from his or her hand to the player.
- The first player creates a molecule with proper Lewis structure utilizing no more than 5 cards in his or her hand. Only neutral stable molecules with no unpaired electrons are allowed, with all atoms having neutral formal charge, and nonbonding electron pairs are included in the structure. Electron count in the structure must equal the sum of the valence electrons on its component atoms. At least one card must be passed back to the player's partner.
- The player then records the enthalpy liberated from the formation of this molecule by recording the total enthalpy of each bond formed in the "Enthalpy of Bonds Created" column.
- The player then replenishes his or her hand with cards from the pile in order to have five cards in his or her hand.
- The next player creates a molecule based on the elements in his or her hand or creates another molecule based on any other molecule on the table. When the player modifies an existing molecule, each bond broken is recorded in the "Enthalpy of Bonds Broken" column. All bonds created are recorded in the "Enthalpy of Bonds Created" column. If this results in the formation of two new molecules, both may stay on the table. Extra atoms, such as those from a substitution go into the recycle pile. Note that a player may not both create a new molecule and modify an existing molecule on the table in one turn. Any molecule that has not been modified for an entire rotation of players is removed from the table and placed in the recycle pile.
- Each player continues in this fashion until all cards are exhausted and no more Lewis structures can be made or modified. When the first player runs out of card, the game proceeds one or two turns until the number of rounds is equal for each team.
- A player who generates an unsuitable Lewis structure and replenishes his or her cards is subjected a penalty of zero score. The player who discovers the mistake may utilize the deficient molecule (in addition to his or her regular turn) and get the energy points gained by correcting it.
- When the game ends each player totals the enthalpy of bonds broken column and subtracts the total enthalpy of bonds created column to obtain their final score. The player with the lowest (most negative) enthalpy score (most stable molecules) wins the game!

Practice:

Use the hands that are shown in the figure to the right, to practice through a few turns of the game.



- Alyssa can make a few different molecules but acetylene will produce release more energy because of the bonds created (see table below). She would record 1665 kJ/mol in the bonds created column and 0 kJ/mol in the bonds broken column.

Acetylene	Formaldehyde
$\text{H}-\text{C}\equiv\text{C}-\text{H}$	$\begin{array}{c} \text{:O:} \\ \\ \text{H}-\text{C}-\text{H} \end{array}$
$2 \times (\text{C}-\text{H}) + (\text{C}\equiv\text{C}) =$ $2 \times (413 \text{ kJ/mol}) + 839 \text{ kJ/mol} =$ 1665 kJ/mol	$2 \times (\text{C}-\text{H}) + (\text{C}=\text{O}) =$ $2 \times (413 \text{ kJ/mol}) + 799 \text{ kJ/mol} =$ 1625 kJ/mol

- For Rex's turn, he could make his own molecule or change Alyssa's. He could change Alyssa's acetylene into dichloroethene and score it according to the table below:

Bonds Broken	Bonds Created
$\text{H}-\text{C}\equiv\text{C}-\text{H}$	$\begin{array}{c} \text{H} \quad \text{H} \\ \diagdown \quad / \\ \text{C}=\text{C} \\ / \quad \diagdown \\ \text{:Cl:} \quad \text{:Cl:} \end{array}$
Breaking $(\text{C}\equiv\text{C}) =$ 839 kJ/mol	$2 \times (\text{C}-\text{Cl}) + (\text{C}=\text{C}) =$ $2 \times (328 \text{ kJ/mol}) + 614 \text{ kJ/mol} =$ 1270 kJ/mol

- Play would continue with each player making or changing molecules on the table. With each turn, remember to trade one card with your partner that you think might be helpful to them in creating a stable molecule.

Bond Type	Ave Enthalpy (kJ/mol)	Bond Type	Ave Enthalpy (kJ/mol)
C—H	413	O—F	190
C—C	348	O—Cl	203
C—N	293	F—F	155
C—O	358	Cl—F	253
C—F	485	Cl—Cl	242
C—Cl	328	Br—F	237
C—Br	276	Br—Cl	218
N—H	391	Br—Br	193
N—N	163	Multiple Bonds	
N—O	201	C=C	614
N—F	272	C≡C	839
N—Cl	200	C=N	615
N—Br	243	N≡C	891
H—H	436	C=O	799
H—F	567	C≡O	1072
H—Cl	431	N=N	418
H—Br	366	N≡N	941
O—H	463	N=O	607
O—O	146	O=O	495

Formal Charge = Valence e^- - e^- assigned to the atoms in the Lewis Structure

Formal Charge = Valence e^- - # Bonds - # of Lone Pair e^-

$$\Delta H = \sum \Delta H(\text{bonds broken}) - \sum \Delta H(\text{bonds created})$$

TEAM NAME:				
Enthalpy of Bonds Broken (kJ/mol)	-	Enthalpy of Bonds Formed (kJ/mol)	=	Net Enthalpy Score
	-		=	
	-		=	
	-		=	
	-		=	
	-		=	
	-		=	
	-		=	
	-		=	
	-		=	
Net Enthalpy Score:				

Net Enthalpy Score = Enthalpy of Bonds Broken – Enthalpy of Bonds Created

Adapted from: Bell, P.T., Adkins, A.D., Gamble, R.J., & Schultz, L.D. (2009).

Enthalpy costs of making and breaking bonds: A game of generating molecules with proper Lewis structures. *Journal of Chemical Education*, 86(4), 450-453.