Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date \_\_\_\_\_\_\_\_\_\_

### Lesson 2.3 Tracing Matter and Energy in Fermentation Worksheet

**A. Using molecular models to show why yeast use fermentation.**

In order for yeast to survive, grow and reproduce, they need energy. Yeast get energy from chemical energy in their food (organic carbon molecules like sugar), just like we do. Food molecules like sugar have C-C and C-H bonds which have more chemical potential energy in them than C-O and H-O bonds.

Yeast have two options for transforming the energy in sugar. If oxygen is available, they can do cellular respiration. This produces carbon dioxide (CO2) and water (H2O). Since carbon dioxide and water have only low-energy bonds (C-O and H-O), the chemical energy is released. Use the molecular models to show how this happens.

If oxygen is not available, yeast do fermentation. This produces carbon dioxide (CO2) and ethanol (CH3CH2OH).

1. Work with your partner to make models of two reactant molecules of sugar (C6H12O6). Using twist ties, show how chemical energy is stored in the high-energy bonds of sugar.
   1. Put these molecules on the *reactant* side of the Process Tool for Molecular Models poster.
   2. Put the “Chemical Energy” card under the sugar molecule to label the energy in the C-C and C-H bonds. Note how many energy units (twisty ties) there are in the sugar molecule.
2. Show how the atoms of one of the reactant molecules can recombine into product molecules—carbon dioxide and ethanol.
   1. Take one of the sugar molecules apart and recombine them into carbon dioxide (CO2) and ethanol (CH3CH2OH) molecules. Put twist ties around each C-C and C-H bonds. Put these molecules on the *product* side of the Process Tool for Molecular Models poster. Some things to notice:
      1. How many carbon dioxide molecules were produced? \_\_\_\_\_
      2. How many ethanol molecules were produced? \_\_\_\_\_
   2. Energy lasts forever. How many twist ties are not in the ethanol, that is how many twist ties are left over?\_\_\_\_\_\_

**B. Atoms last forever!!** Check yourself: did your number and type of atoms stay the same at the beginning and end of the chemical change? Use the table below to account for all the atoms and bonds in your models.

**Energy lasts forever!** Write the type of energy for reactants and products in the chemical change.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Matter** | | | **Energy** | |
|  | How many  carbon atoms | How many  oxygen atoms | How many  hydrogen atoms | How many twisty ties? | What forms of energy? |
| *Begin with…* |  |  |  |  |  |
| Sugar |  |  |  |  |  |
| Total in reactants |  |  |  |  |
| *End with…* |  |  |  |  |  |
| Carbon Dioxide |  |  |  |  |  |
| Ethanol |  |  |  |  |
| Total in products |  |  |  |  |

**C. Writing the chemical equation.** Use the molecular formulas (C6H12O6, CO2, CH3CH2OH) and the yield sign (🡪) to write a balanced chemical equation for the reaction:

**D. The fermentation energy puzzle.** We said that fermentation was an alternative to cellular respiration that yeast could use when no oxygen was available. But fermentation does not appear to release energy. We started with 12 twist ties (high energy bonds) in the sugar molecule and we ended up with 12 in the two ethanol molecules.

The problem is that we have not been entirely accurate in our energy accounting. We have counted C-C and C-H bonds as being equal. In fact, C-H bonds don’t have quite as much energy in them as C-C bonds. Breaking a C-C bond and forming a C-H bond yields some energy. Let’s use this information to re-evaluate the energy transformations associated with fermentation.

Use your molecular models to answer the following questions.

|  |  |
| --- | --- |
| **Reactant** | **Products** |
| How many C-C bonds are in the initial sugar molecule?\_\_\_\_\_\_\_\_\_ | How many C-C bonds are in the resulting ethanol molecules?\_\_\_\_\_\_\_\_\_ |
| How many C-H bonds are in the initial sugar molecule?\_\_\_\_\_\_\_\_\_ | How many C-H bonds are in the resulting ethanol molecules?\_\_\_\_\_\_\_\_\_ |
| How many C-C bonds were broken and reformed as C-H bonds?\_\_\_\_\_\_\_\_\_ | |

**E. Summarizing what we know about fermentation.** We have learned that yeast have two options for how they use molecules like sugar for energy.

* In the presence of oxygen, they can do cellular respiration resulting in the production of carbon dioxide and water.
* When no oxygen is present, they can do fermentation resulting in the production of carbon dioxide and ethanol.
* We also learned that ethanol can be burned (undergo combustion) resulting in the production of carbon dioxide and water.

Place these substances on the chemical energy diagram below. Placing a substance higher on the diagram means that it has more chemical energy.

* Sugar
* Ethanol

Chemical

Energy

* Carbon dioxide and water

1. Use what you’ve learned about the energy transformations in the diagram above to explain why yeast grow much faster in environments where they have oxygen than in environments without oxygen. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. Carbon dioxide and water and ethanol are produced from sugar by the carbon-transforming processes cellular respiration and fermentation. Explain why we can use ethanol, but not carbon dioxide, as a fuel.

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Now summarize what we’ve learned using the Three Questions for FERMENTATION Process Tool below.

