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1. (a) The relationship between energy and work is that energy is the ability to do work. Work is done when an object is moved by using energy.

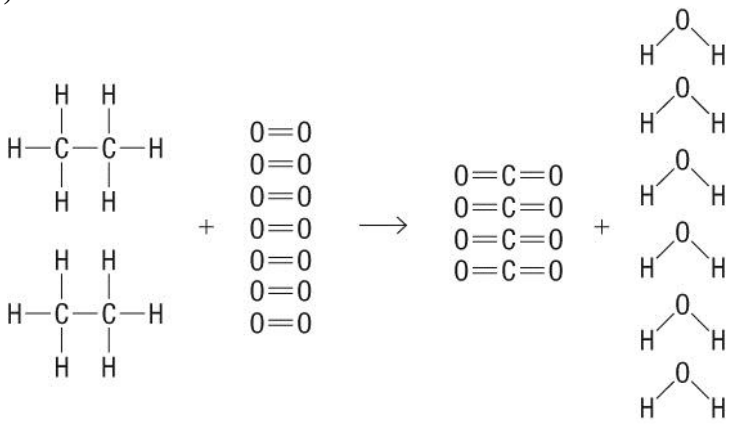
(b) The relationship between potential energy and kinetic energy is that potential energy is energy associated with position or structure of an object and can be converted into kinetic energy—the energy associated with motion.

(c) The relationship between free energy and spontaneous changes is that free energy is energy available to do work and spontaneous changes result in a reduction of free energy in the system.

2. The relationship between bond energy and energy changes that occur during a chemical reaction is bond energy is the energy needed to break a bond or the energy released when a bond forms and energy changes that occur are a result of the comparison between the chemical potential energy of the products and the chemical potential energy of the reactants. During any chemical reaction some energy is absorbed when bonds in the reactants break and some energy is released when bonds form in the products. This change in bond energy is measured as the energy change of a reaction.

3. (a) (i) $2\ C_2H_6 + 7\ O_2 \rightarrow 4\ CO_2 + 6\ H_2O$

(ii)



(iii) Reactants

Bond	Average bond energy (kJ/mol)	Number of bonds in propane	Number of bonds in oxygen	Total bond energy
C–H	411	12		4932
O–H	459			
C–C	346	2		692
C–O	359			
C=O	799			
O=O	494		7	3458

total bond energy = 5 624 kJ + 3458 kJ
= 9 082 kJ

Products

Bond	Average bond energy (kJ/mol)	Number of bonds in water	Number of bonds in carbon dioxide	Total bond energy
C–H	411			
O–H	459	12		5508
C–C	346			
C–O	359			
C=O	799		8	6392
O=O	494			

total bond energy = 5508 kJ/mol + 6392 kJ/mol
= 11 900 kJ/mol

(iv) net energy change = total bond energy of products − total bond energy of reactants
= 11 900 kJ/mol − 9082 kJ/mol
= 2818 kJ/mol

(v) molar mass of ethane C_2H_6 = 30 g/mol

(vi) determine energy = (energy per mol)/ (number of mol)
= (2 818 kJ/mol)/ ((2) (30 g/mol))
= 47 kJ/g

vii) The amount of energy released from the combustion of ethane with oxygen is 47 kJ/g. This makes this reaction exothermic.

(b) There is much more energy per gram from ethane than from either glucose (15 kJ/g) or butanoic acid (23 kJ/g).

(c) Hydrocarbons have the highest energy content followed by fats and then carbohydrates. This is because hydrocarbons contain a higher ratio of high-energy C–H bonds per carbon than the other molecules do.

4. Given: $E_{products}$ = 1386 kJ/mol
$E_{reactants}$ = 1250 kJ/mol

Required: ΔE

Analysis: $\Delta E = E_{products} - E_{reactant}$

Solution: ΔE = 1386 kJ/mol −1250 kJ/mol
= 136 kJ/mol

Statement: Overall, there is a net release of 136 kJ/mol, so the reaction is exothermic.

7. The difference between anabolic and catabolic pathways is the change in free energy as a result of the reaction. An anabolic pathway is a process in which complex molecules are built from simpler ones, requiring free energy. A catabolic pathway is a process in which large complex molecules are broken down into simpler ones, releasing free energy.