Efficiency

$$\frac{\text{Useful energy}}{\text{Total energy}} \times 100 = \%\ \text{efficiency}$$

1. A camper used a Trangia, shown on the right, to heat 500 grams of water at 24.0 °C. Ethanol has a chemical energy density of 29.7 kJ/g. A mass of 5.00 grams ethanol was burnt to raise the temperature of the water to 58.5 °C.

a. Calculate the amount of energy, in kJ, released by the burning of 5.00 grams of pure ethanol.

5.00 X 29.7 kJ = 148.5 kJ

b. Calculate the amount of heat, in kJ, transferred to the water.

4.18 X 500 X 34.5 = 72.1 kJ

c. Calculate the efficiency, to the right number of significant figures, of the energy transformation of the Trangia.
(energy efficiency % = (useful energy / total energy) X 100)

(72.1 / 148.5) X 100 = 48.6%

d. Give two factors that might impact the efficiency of the energy transformation during the combustion of the ethanol. Explain how each factor will impact the efficiency.

i. *Purity- the less pure the fuel the greater the mass of fuel needed to deliver a given amount of energy.*

ii. *Insulation - a poorly insulated heater will lose a great deal of heat and hence more fuel needs to be burnt to achieve a given temperature increase of the water.*
Any other suggestion with a viable explanation is accepted.

2. A car engine is known to have an efficiency of 35%. If the engine consumes 30.00 litres of petrol in one single journey, calculate the amount of energy, in MJ, energy available for useful work done by the engine and determine the wasted energy in the form of heat. Assume that the energy content of petrol is approximately 3.42 X 10^4 kJ/L.
Step 1 Find the total amount of energy available form 30.00 litres of petrol.
=> 30.00 X 3.42 X 10^4 kJ = 1.02 X 10^6 kJ
Step 2 Find the energy available to the engine.
=> 0.3500 X 30.00 X 3.42 X 10^4 kJ. = 3.59 X 10^5 kJ
Step 3 Find the energy wasted as heat.
=> 1.02 X 10^6kJ - 3.59 X 10^5kJ = 6.61 X 10^5kJ = 6.61 X 10^2MJ.

3. A volume of 0.500 L of octane has a mass of 351 g at SLC. The efficiency of the reaction when octane undergoes combustion in a new design of a car engine is 35.0%. What volume, in litres, is required to produce 438 MJ of usable energy in this type of combustion engine at SLC? Give the answer to the right number of significant figures.
Step 1 Calculate the mass of octane needed to deliver 438 MJ if 100% efficiency
=> Find mass, in grams, of octane needed to deliver 438 X 10^3 kJ of energy.
= 4.38 x 10^5 kJ / 47.9 kJ/g
= 9.144 X 10^3 g

Step 2 Calculate the density of octane at SLC.

=> 351g/0.500L = 702g/L
Step 3 Calculate the volume in litres

=> 9.144 X 10^3g / 702g/L = 13.0 litres

Step 4 Find the volume needed if 35% efficient.

=> 13.0 / 0.35m = 37.2 litres.

4. The human body converts chemical energy from food into mechanical energy at an efficiency of 25.0 %. A food-bar has the label shown on the right. A person climbing a staircase requires 20.00 MJ of mechanical energy. Assuming this energy is to come solely from the food-bar, what mass, in kilograms, of this food-bar must be consumed to derive just enough energy to climb the stairs.
Step 1 Assuming 100% efficiency find the number of 100 gram food bars necessary to deliver 20.00 MJ of mechanical energy.
=> 20.00 / 1.550 = 12.90 (100 gram food bars)
=> 1.290 kg
Step 2 Since the process is 25.0% efficient we would require
=> 1.290 / 0.250 = 5.16 kg.

Nutrition Information

	Average Quantity per 100 g	
Energy	1550	kJ
Protein	0.0	g
Fat, total	4.7	g
- saturated	2.1	g
- trans	0.0	g
Cholesterol	0.0	mg
Carbohydrate	80.9	g
- sugars	52.6	g
Sodium	120	mg

5. Glucose is used as a fuel in the human body in a process called cellular respiration and is also used to produce bioethanol through the process of fermentation.

a. Give the balanced chemical equations, states not included, for:

i. Fermentation

$C_6H_{12}O_6 \rightarrow 2C_2H_6O + 2H_2O$

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ii. Cellular respiration

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

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b. Glucose can also be used as a fuel in implantable, acidic fuel cells to produce electrical energy inside the human body. The fuel cell uses glucose and oxygen dissolved in the blood to produce the necessary energy according to the reaction shown below.

$$2C_6H_{12}O_6 + O_2 \rightarrow 2C_6H_{12}O_7$$

i. Given that the use of glucose in both cellular respiration and in implantable fuel cells represents a redox reaction, write the oxidation half equation, states not included:

- for cellular respiration

$6H_2O + C_6H_{12}O_6 \rightarrow 6CO_2 + 24H^+ + 24e$

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- in an implantable glucose fuel cell.

$H_2O + C_6H_{12}O_6 \rightarrow C_6H_{12}O_7 + 2H^+ + 2e$

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ii. Compare the efficiency of the utilisation of chemical energy in glucose in both the processes of cellular respiration and as a reactant in an implantable fuel cell.

1. *Greater efficiency in chemical energy release during cellular respiration than during release of energy in implantable fuel cells.*
2. *Glucose in a fuel cell undergoes partial oxidation. C in glucose, during cellular respiration, changes oxidation state from 0 in glucose to +4 in CO_2. Whilst, C in glucose, used as a fuel in implantable fuel cells, changes from 0 to +1/3. This indicates a greater degree of oxidation during cellular respiration than during oxidation in a fuel cell. Hence more energy released during cellular respiration.*
3. *The oxidation half equations of both processes reveals a 12 fold increase in electrical energy released during cellular respiration than in the fuel cell with 24 electrons released per molecule of glucose oxidised during cellular respiration as opposed to 2 electrons for each molecules of glucose oxidised in a fuel cell.*