

Module 4: Energy

Answers to Further exercises

- A1.** Our food is more highly refined and processed and this consumes more energy.
Our houses are larger and more elaborate and building them requires more energy.
We heat, light and cool our houses to greater extents and this uses much energy.
Our clothes require more energy for their manufacture and we have many more of them and often throw them away before they are worn out.
We travel more in our daily routines and on holidays and generally use energy-consuming vehicles for this (cars, buses, trains, planes).
Our forms of entertainment and recreation (movies, theatre, music, sport, holidays) use much more energy.
We have many more possessions and the manufacture of these consumes much energy.
The types of industries we work in and the education and training we undergo use much more energy than those in less developed rural communities.
(and there are many more you may have listed.)
- A2.** Walk or ride bicycles instead of using cars, trains and buses.
Make sure the cars we buy are no bigger than we really need, buy the most energy efficient models, and don't drive them unnecessarily: car pool with friends and neighbours when possible.
Live close to where we work (or vice versa) so as to minimise transport energy to get to and from work.
Eat simple foods that involve minimum processing and/or cooking such as fresh fruit and vegetables with less emphasis on meats.
Keep clothes, consumer and household goods for longer periods of time and repair them rather than replace them with new ones.
Reuse goods and materials and recycle them when they are no longer reusable.
Build houses that are designed to be cool in summer and warm in winter (it is possible!) and so minimise requirements for heating and cooling.
Wear clothes that are appropriate to the climate (weather) in order to minimise heating and cooling of buildings.
Choose sporting and recreational activities that use minimum energy (such as avoiding snow and water skiing), run, swim, bushwalk or play sport instead of using energy consuming machines in gyms.
(and there are many more you may have thought of.)
- A3.** The foods we eat, particularly cereal products (from grains), vegetables and fruit and meat provide us with the energy we need for living and for our daily activities (in addition to the building blocks for growth, cell renewal and healthy metabolism such as amino acids via proteins, vitamins and minerals). This energy comes to us from photosynthesis: plants convert solar energy (sunlight) into chemical energy that is stored in compounds such as sugars and starch. When we eat those foods that stored energy is released. In effect then we are eating sunlight. When we eat meat, poultry or fish the sunlight comes to us in a two-step process: from plants to animals then to us.
In modern-day farming there are lots of other energy inputs to produce the grains, fruits, vegetables and meats that we eat and these other energy inputs generally come from fossil fuels, particularly from oil. Land is ploughed with tractors, crops are irrigated with pumping equipment and treated with fertilisers made in chemical plants, crops are harvested by machines, transported to processing or packaging plants by truck, often processed with machinery, then packaged in containers that required energy for their making then transported to markets (shops). Finally it is carried home generally by other transport (cars) and cooked using gas or electricity before it is finally eaten. All of these processes require energy which comes directly (diesel, petrol or oil) or indirectly (from electricity that came from coal) from fossil fuels. When these fossil fuel inputs are added up, they are frequently greater than the amount of solar energy stored in the food. Hence we can say that when

we eat food we are eating fossil fuel as well as sunlight.

- A4.**
1. Some of the electricity we use (about 6%) comes from hydroelectricity.
 2. Windmills (wind power) is sometimes used to pump water from wells into storage tanks.
 3. Sugar mills (for extracting sugar from sugar cane) are powered by burning bagasse (the fibrous residue of the cane after the sugar has been extracted).
 4. In some parts of the world (not Australia) significant proportions of electricity requirements are generated from nuclear reactors (nuclear energy).
 5. In various places around the world small amounts of electricity are now being generated by wind turbines, tidal energy, geothermal energy and focused solar collectors.
 6. Methane is being collected from urban garbage tips and sewage treatment works and used to generate electricity. This is methane from anaerobic decomposition of organic matter, not from natural gas so is not a fossil fuel here.
- (If you found this question hard to answer, that just emphasises how heavily we rely on fossil fuels for our energy needs!)

Currently from fossil fuels but which could come from non-fossil-fuel sources:

1. Hot water from a solar hot water system (instead of from a gas or electric heater).
2. Drying laundry in sunlight instead of using an electric clothes dryer.
3. Running a car on ethanol made from sugar cane instead of on petrol. Or running a car on solar panels (photoelectric cells) on the top of the car (only experimental at this stage).
4. Some household electricity could be generated from panels of solar cells (photovoltaic cells) mounted on the roofs of houses.
5. Solar powered garden lights (photoelectric cells store energy in a battery for use at night) instead of ones operated by mains electricity.
6. Hand operated garden tools instead of powered ones (such as mower, hedge clippers, power blower-vac for 'raking' up leaves).
7. Wood-burning stove for home heating instead of gas or electric heaters (but see Exercise K1).

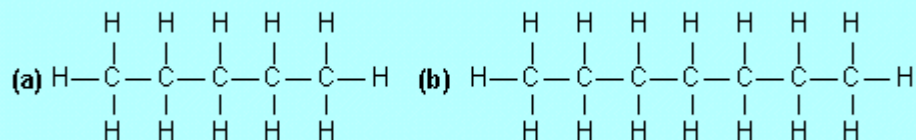
- B1.** Silicon is in the same group of the Periodic Table as carbon so like carbon it can form four covalent bonds. SiC has the same structure as diamond (CCPC page 249) but with every second C replaced by an Si atom. This gives SiC similar properties to diamond.

B2.



- B3.** Double bond: b, d; they have formulae that are consistent with the general formula of alkenes, C_nH_{2n} .

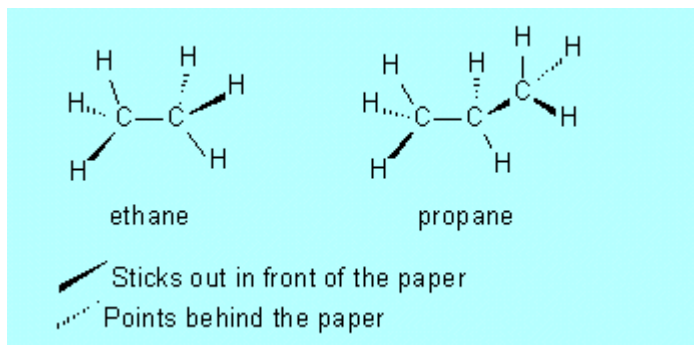
C1.



- C2.** Hydrocarbons are compounds that contain hydrogen and carbon only. Alkanes are hydrocarbons that have the general formula C_nH_{2n+2} or are hydrocarbons in which all the bonds are single bonds. There are several other types of hydrocarbons, such as ones that contain double or triple bonds and which have different general formulae. Therefore all alkanes are hydrocarbons but not all

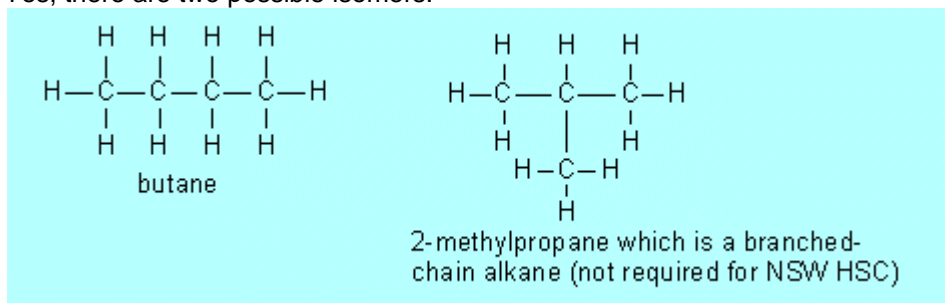
hydrocarbons are alkanes. In other words alkanes are a sub-set of hydrocarbons: that is what 'sub-set' means.

C3.



The arrangement of the four bonds around each carbon atom is tetrahedral. That means that the carbon atom is at the centre of a tetrahedron with the four atoms attached to it located at the apexes of the tetrahedron.

C4. Yes, there are two possible isomers:

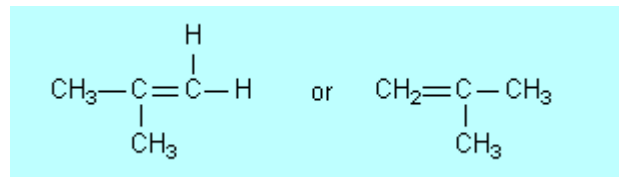


D1. (a) 20.1% H, 79.9% C; (b) 15.9% H, 84.1% C

The general formula for alkenes is C_nH_{2n} , meaning that all alkenes have the same empirical formula CH_2 . This means that the ratio of H to C atoms is always the same in alkenes and so it follows that the mass ratio will always be the same, 14.4% H and 85.6% C.

Alkanes have the general formula C_nH_{2n+2} . So most alkanes will have different empirical formulae, meaning that the ratio of H to C atoms varies from one alkane to another and so the per cent composition will vary as our two examples above show.

D2.



This compound is called 2-methyl-1-propene. It is a branched chain hydrocarbon; branched chain compounds are not required for the NSW HSC.

F1. Keep it away from any naked flames or hot surfaces such as stoves or heaters.

Store it in a strong container with a narrow mouth and a good screw-top lid (preferably metal, and avoid disposable (flimsy) plastic bottles).

Make sure that the container is clearly labelled 'kerosene' and 'highly flammable'.

Keep it out of reach of young children.

Do not keep larger quantities than are absolutely necessary.
When using it or transferring it from one container to another do so in a well-ventilated place and avoid confined spaces such as small storerooms or enclosed garages.
Avoid inhaling the substance.

The compounds present in kerosene are all colourless. Kerosene is blue because a dye is added to it to make identification in the home easy, that is as a safety precaution. (Many years ago blue colouring for foods was not allowed, so anything blue was non-edible, but that restriction has now disappeared.)

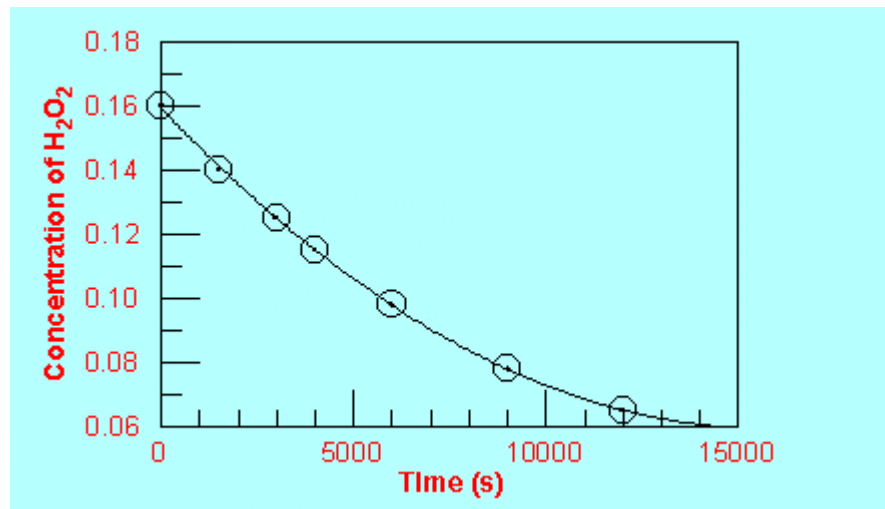
- F2.** (a) natural gas; (b) petrol; (c) LPG, cigarette lighters or disposable gas canisters for bushwalkers and blow torches; (d) kerosene or diesel fuel; (e) mineral turps (paint thinner); (f) vaseline, paraffin wax and lubricating greases for motor cars.
- G1.** $\text{Ba}(s) + 2\text{H}_2\text{O}(l) \rightarrow \text{Ba}(\text{OH})_2(aq) + \text{H}_2(g)$; -704 kJ/mol (using $100 \times 4.2 \times 12.2$) or -710 kJ/mol (using $101 \times 4.2 \times 12.2$).
- G2.** $\text{CaO}(s) + \text{H}_2\text{O}(l) \rightarrow \text{Ca}(\text{OH})_2(aq \text{ or } s)$; -80 kJ/mol (using $100 \times 4.2 \times 4.2$) or -81 kJ/mol (using $103.1 \times 4.2 \times 4.2$).
- H1.** $2.9 \times 10^3 \text{ kJ/mol}$
- J1.** Break a C–H and a Cl–Cl bond, make a C–Cl and a H–Cl bond; taken together the bonds being made are stronger than the bonds being broken, or in other words more energy is released when a C–Cl and a H–Cl bond are formed than when a C–H and a Cl–Cl bond are formed.
- J2.** (a) $\Delta H = -160 \text{ kJ/mol}$ (± 20); $E_a = 250 \text{ kJ/mol}$ (± 20).
(b) $\Delta H = +40 \text{ kJ/mol}$ (± 10); $E_a = 80 \text{ kJ/mol}$ (± 10).
- K1.** Burning wood just releases to the atmosphere the carbon dioxide that was taken from the atmosphere by the trees when they grew the wood, so although the time scale is long the carbon dioxide is being recycled. So in a steady state situation – wood being burnt equals wood being grown – it would not increase the carbon dioxide concentration in the atmosphere. Even in the current state – wood being burnt greater than wood being grown – some of the released carbon dioxide is being reabsorbed by trees. On the other hand the carbon dioxide formed by burning natural gas comes from carbon that had been locked in the Earth for hundreds of millions of years as fossil fuel and so this is an added load for the atmosphere and thus contributes to increasing concentrations of carbon dioxide in the atmosphere and so to global warming.
The disadvantage of burning wood is that it releases a lot of pollutants to the atmosphere – carbon monoxide and soot (smoke) from incomplete combustion and many odoriferous vapours (compounds of low flammability). This is particularly so in slow combustion stoves where only the minimum amount of air is used (to stop the wood burning too quickly and so wasting heat) and where the combustion temperature is too low for complete combustion. These pollutants are not obvious to the occupants of the house because slow combustion stoves vent them to the outside and not into the room being warmed.
Other disadvantages are that collecting wood for home heating can lead to destruction of or damage to natural forests and destruction of habitats for native animals and birds (many of which live in hollows of dead trees or fallen logs).
- K2.** $\text{C}_8\text{H}_{18}(g) + 12\frac{1}{2}\text{O}_2(g) \rightarrow 8\text{CO}_2(g) + 9\text{H}_2\text{O}(g \text{ or } l)$
 $\text{C}_8\text{H}_{18}(g) + 11\text{O}_2(g) \rightarrow 5\text{CO}_2(g) + 3\text{CO}(g) + 9\text{H}_2\text{O}(g \text{ or } l)$ (any combination of CO_2 and CO is acceptable as long as the equation is balanced)

$C_8H_{18}(g) + 8O_2(g) \rightarrow 2CO_2(g) + 3CO(g) + 3C(s) + 9H_2O(g \text{ or } l)$ (again any combination of CO_2 , CO and C is acceptable as long as the equation is balanced)

- (a) excess air and a high combustion temperature.
 (b) limited supply of air and a low combustion temperature.

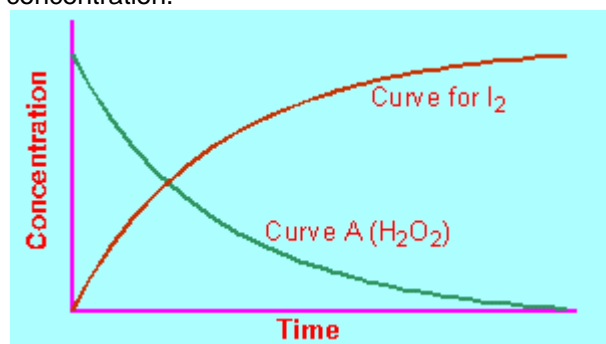
K3. A high ratio of air to fuel favours complete combustion of the fuel and so minimal amounts of carbon monoxide and unburnt fuel are produced: it also leads to a higher combustion temperature (quicker burning). However the higher concentrations of oxygen and nitrogen gases and the higher combustion temperature lead to formation of greater amounts of nitric oxide (from $N_2 + O_2 \rightarrow 2NO$) and hence of more NO_2 ($2NO + O_2 \rightarrow 2NO_2$).

L1.



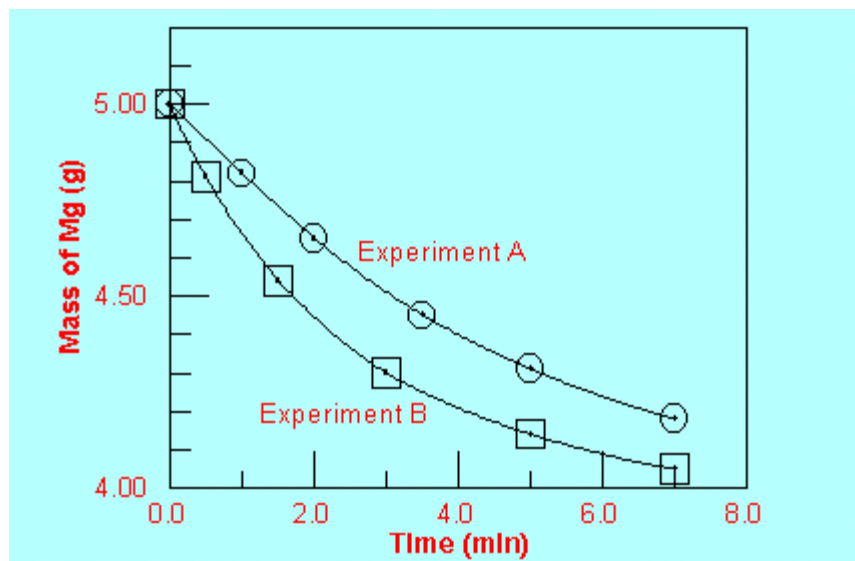
Over first 3000 s average rate is $1.16 \times 10^{-5} \text{ mol L}^{-1} \text{ s}^{-1}$
 From 5000 to 8000 s average rate is $7.3 \times 10^{-6} \text{ mol L}^{-1} \text{ s}^{-1}$
 From 10000 to 12000 s average rate is $4.5 \times 10^{-6} \text{ mol L}^{-1} \text{ s}^{-1}$
 Reaction rate decreases as reaction proceeds.

L2. Curve A belongs to 0.20 mol/L iodide while Curve B belongs to 0.40 mol/L. Curve B has the steeper initial slope so has the faster rate of reaction. Reaction rate usually increases as concentration of reactant is increased so Curve B must belong to the higher iodide concentration.



L3. (a) $Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$
 (or simply $Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$)

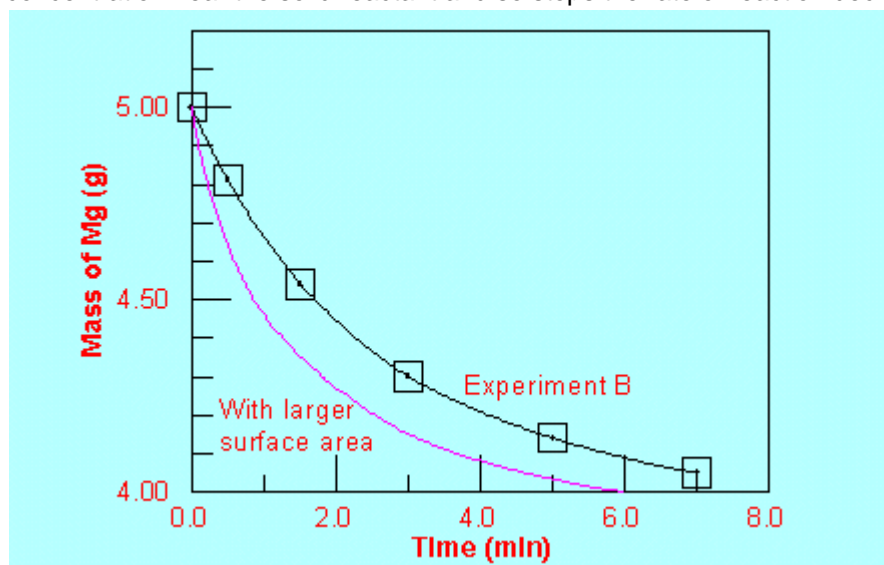
(b)



(c) Stirring increases the rate of reaction. The initial slope of the curve for Experiment B is steeper (more negative) than for Experiment A so Experiment B has the greater rate of reaction; the only difference between the two experiments is the stirring so stirring must increase the rate of reaction.

(d) Stirring increases the rate of a heterogeneous reaction because it keeps bringing fresh (unreacted) solution into contact with the surface of the solid. Without stirring the solution in contact with the solid becomes depleted in reactant (as it gets used up) and as reactant concentration falls so rate of reaction falls. Stirring prevents localised decreases in reactant concentration near the solid reactant and so stops the rate of reaction decreasing too quickly.

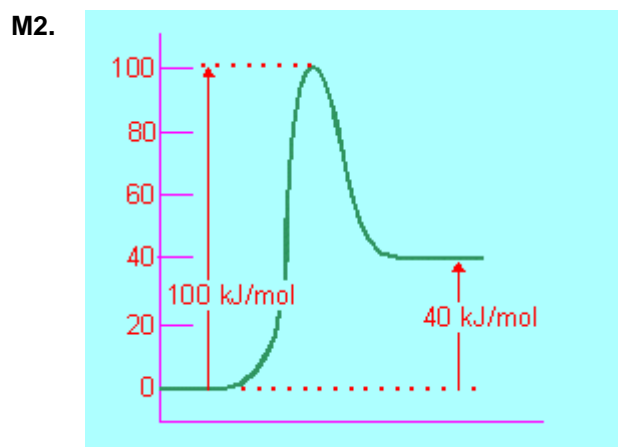
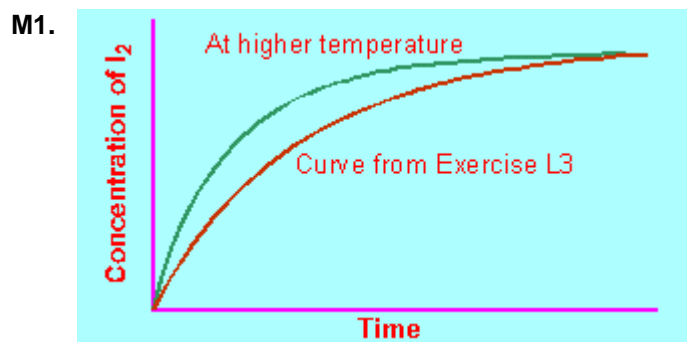
(e)



If the magnesium were thinner, then the 5.00 g would have a larger surface area. Heterogeneous reactions between a solid and a solution occur on the surface of the solid so if there is a greater surface area of solid, the reaction rate will be greater in the early stages of the reaction. The rate will fall off as the concentration of reactant in the solution is depleted. Hence the curve will have a steeper slope initially but it will fall off as reaction proceeds as shown in the graph.

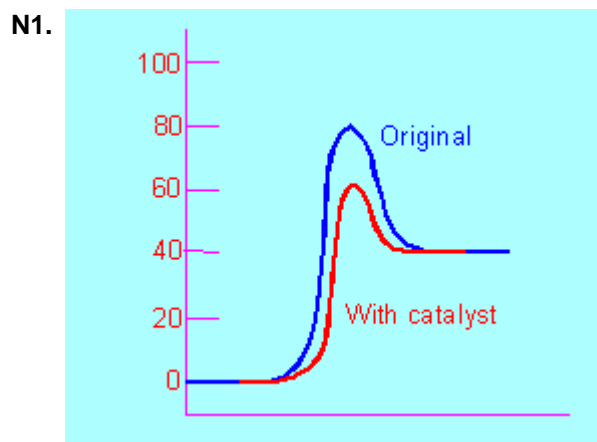
L4. Experiment A: $0.18 \text{ g Mg min}^{-1}$

Experiment B: $0.34 \text{ g Mg min}^{-1}$



For the reverse reaction $\Delta H = -40 \text{ kJ/mol}$, $E_a = 60 \text{ kJ/mol}$

M3. By breaking up the solid into small particles and stirring the mixture to keep the particles well dispersed throughout the solution. Heating the mixture would also help.



N2. Yes, because Cl is not consumed in the overall reaction.

N3. To avoid risk of a fire or explosion. While starch (flour) in bulk is not particularly flammable, when it is dispersed as fine particles in a plentiful supply of oxygen (air) it is much more easily ignited so fires or explosions can occur.

N4. So that there is enough CO around to convert all the NO to N_2 . If reaction (b) is too fast, it will oxidise all the CO before the CO can reduce all the NO.

Vary the relative amounts (or more precisely the surface areas) of rhodium and platinum in the catalytic converter; more rhodium will speed up the CO + NO reaction. (In catalytic converters both catalysts are deposited as a fine film on the surface of a ceramic honeycomb block (*CCPC* pages 314-5).) Depositing the rhodium at the upstream end of the ceramic block would also help.