Unit 1 REVIEW

1 $Q_{\text{lost hot water}} = Q_{\text{gain cold water}}$

$mc\Delta T_{hw} = mc\Delta T_{cw}$

$\cancel{mc}(T_{ihw} - T_f) = \cancel{mc}(T_f - T_{icw})$

$2T_f = T_{icw} + T_{ihw}$

$T_f = \frac{80.0 + 10.0}{2}$

$= 45.0°$

2 **a** Correct. The water in the wet cloth requires energy to evaporate. It obtains this latent heat of evaporation from the bottle and its contents, thereby decreasing the temperature of the contents.

b Incorrect. The temperature of the boiling water will remain constant. All heat added during this time is causing the water to change state not temperature.

c Correct. Obviously the amount of steam or water in question would make a difference since the heat is proportional to the mass.

If the masses are equal, the steam will burn more severely because of the additional latent heat that is released when it condenses to water on the person's skin at 100°C.

3 **a** A fuse protects against overload current in the total circuit. It prevents overheating of the wiring due to excess current as this poses a fire hazard. An RCD detects an imbalance between current entering and leaving a device, which suggests there is some earth leakage with that current flowing to earth. Both will shut down the circuit.

b A short circuit is a fault in the circuit that connects the active and neutral wires, effectively bypassing the load in the circuit. This means there is a greatly reduced resistance due to the absence of a load, causing a high current to flow. This condition will trigger the circuit breaker.

c Plugs with three prongs have an active, a neutral and an earth pin. The connection of an earth is required when there is any possibility that the active lead could contact the metal casing of an appliance and risk electrocution of the user as they become the contact to earth. Some smaller devices are double insulated and so the active wire cannot deliver charge to any part of the device that a user can touch. In this case, the earth is not needed and the plug can safely have only two prongs.

4 **a** ${}^{7}_{3}\text{Li} + {}^{1}_{1}\text{H} \rightarrow 2\,{}^{4}_{2}\text{He}$

b ${}^{185}_{79}\text{Au} \rightarrow {}^{4}_{2}\text{He} + {}^{181}_{77}\text{Ir}$

c ${}^{218}_{81}\text{Tl} \rightarrow {}^{218}_{82}\text{Pb} + {}^{0}_{-1}\text{e}$

5 **a** Electrostatic forces of repulsion act on the protons. They do not have enough energy to overcome this force to get close enough for the strong nuclear force to come into effect and hence will not fuse. These protons have not jumped the energy barrier.

b Electrostatic forces of repulsion act on the two protons initially, but the protons have enough energy to push past these forces and get close enough together for the strong nuclear forces to take effect. This force enables the nucleons to fuse. These protons have overcome the energy barrier.

6 **a** The energy of the photons results from the conversion of the mass of the electron and positron to energy.

b $E_{comb} = m_{e-}c^2 + m_{e+}c^2$

$= (9.11 \times 10^{-31}) \times (3.00 \times 10^8)^2 + (9.11 \times 10^{-31}) \times (3.00 \times 10^8)^2$

$= 1.64 \times 10^{-13}$ J

$= \frac{(1.64 \times 10^{-13})}{(1.60 \times 10^{-19})}$

$= 1.03 \times 10^6$ eV

$= 1.03$ MeV

7 **a** The binding energy of a nucleus is the energy that would be needed to break the nucleus into its component nucleons. The binding energy per nucleon is this total value divided by the number of nucleons in the nucleus.

b From the graph, it can be seen that iron atoms have the highest binding energy per nucleon. Iron atoms require the most energy per nucleon to break up their nucleus, therefore they are the most stable.

c The energy per nucleon for uranium is about 7.5 MeV and the binding energy per nucleon for fragments of mass number 118 is about 8.5 MeV. That means that when the smaller fragments are formed, they are more tightly bound and the difference in energy is released in the fission reaction. This is about 1 MeV for each nucleon.

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8 Power input to motor = $VI = 6.0 \times 0.25 = 1.5\,W$

Power output = $\frac{4.0}{5.0} = 0.8\,W$

Efficiency = $\frac{0.8}{1.5} \times 100 = 53\%$

9 **a** $Q_{vN} = m_N L_{vN}$

$= 1.00 \times (1.99 \times 10^5)$

$= 1.99 \times 10^5\,J$

b $Q_{gain\ N} = m_N c_N \Delta T_N$

$= 1.00 \times (1.34 \times 10^3) \times (273.0 - 77.0)$

$= 2.63 \times 10^5\,J$

c $Q_{lost\ s+c} = m_{s+c}\, c_{s+c} \Delta T_{s+c} + m_w L_{fw}$

$= 0.200 \times (3.80 \times 10^3) \times (8.0 - 0.0) + (0.70 \times 0.200) \times (3.34 \times 10^5)$

$= 6.08 \times 10^3 + 4.676 \times 10^4$

$= 5.28 \times 10^4\,J$

d $Q_{lost\ s+c} = Q_{gain}$

$m_{s+c} c_{s+c} \Delta T_{s+c} + m_w L_{fw} = m_N c_N \Delta T_N + m L_{vN}$

$5.28 \times 10^4 = m_N \times (1.34 \times 10^3) \times (273.0 - 77.0) + m_N (1.99 \times 10^5)$

$5.28 \times 10^4 = (2.626 \times 10^5\ m_N) + (1.99 \times 10^5\ m_N)$

$m_N = \frac{5.28 \times 10^4}{4.6164 \times 10^5}$

$= 0.114\,kg$

10 **a** ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{140}_{55}Cs + {}^{93}_{37}Rb + 3\,{}^{1}_{0}n$

b $m_{reactants} = 235.07295 + 1.00899$

$= 236.08194\,u$

$m_{products} = 139.96265 + 92.95241 + 3 \times (1.00899)$

$= 235.94203\,u$

$\Delta m = m_{reactants} - m_{products}$

$= 236.08194 - 235.94203$

$= 0.13991\,u$

$E = u \times 931$

$= 0.13991 \times 931$

$= 130\,MeV$

$= 1.30 \times 10^8\,eV$

$E = (1.30 \times 10^5) \times (1.60 \times 10^{-19})$

$= 2.08 \times 10^{-11}\,J$

Alternative solution:

$m_{reactants} = (3.90221 \times 10^{-25}) + (1.67493 \times 10^{-27})$

$= 3.918959 \times 10^{-25}\,kg$

$m_{products} = (2.32338 \times 10^{-25}) + (1.54301 \times 10^{-25}) + 3 \times (1.67493 \times 10^{-27})$

$= 3.916638 \times 10^{-25}\,kg$

$\Delta m = m_{reactants} - m_{products}$

$= (3.918959 \times 10^{-25}) - (3.916638 \times 10^{-25})$

$= 2.32140 \times 10^{-28}\,kg$

$E = \Delta mc^2$

$= (2.32140 \times 10^{-28}) \times (3.00 \times 10^8)^2$

$= 2.09 \times 10^{-11}\,J$

$E = \frac{2.09 \times 10^{-11}}{1.60 \times 10^{-19}}$

$= 1.31 \times 10^8\,eV$

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c $N_{U-235} = \frac{1.00}{3.90221 \times 10^{-25}} = 2.56265 \times 10^{24}$ atoms

$E_{total} = N_{U-235} \times E$

$= (2.56265 \times 10^{24}) \times (2.09 \times 10^{-11})$

$= 5.36 \times 10^{13}$ J

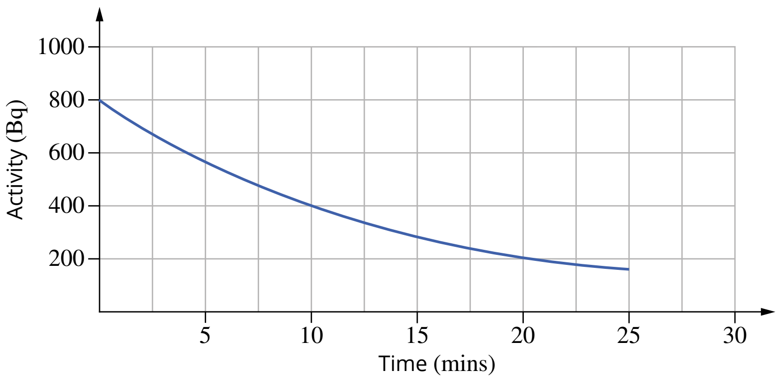
d $m_{U-235} = \frac{E_{per\ day}}{E_{per\ kg}}$

$= \frac{(9.76 \times 10^{13})}{(5.35 \times 10^{13})}$

$= 1.82$ kg

e The conversion of energy released in the reaction to the final generation of electricity is fairly inefficient and has many losses. The energy released in the fission reactions as heat must first be used to heat up water to produce steam to drive the generators. There are many opportunities for energy losses in this system.

11 a



b From the graph, after 13 minutes, the activity is about 320 Bq.

c Find the time at which activity has been reduced from 800 Bq to 400 Bq:

$t_{\frac{1}{2}} \approx 10$ min

d From the graph, extrapolate to find the activity when $t = 30$ min.

Activity ≈ 100 Bq

12 a $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{100} + \frac{1}{200} + \frac{1}{600} = R_T = 60\,\Omega$

b $I = \frac{\Delta V}{R} = \frac{120}{60} = 2.0$ A

c $I_1 = \frac{\Delta V}{R_1} = \frac{120}{100} = 1.20$ A, $I_2 = \frac{\Delta V}{R_2} = \frac{120}{200} = 0.60$ A, $I_3 = \frac{\Delta V}{R_3} = \frac{120}{600} = 0.20$ A

d $P = \Delta VI = 120 \times 2.0 = 240$ W

e $P = I_2R_1 + I_2R_2 + I_2R_3 = 1.20^2 \times 100 + 0.60^2 \times 200 + 0.20^2 \times 600 = 240$ W

13 a This is the naturally occurring radiation that is around us every day. It can come from the Sun, outer space, materials in the Earth's crust and the food we eat.

b The burning of coal (as well as other fossil fuels) releases radioactive materials into the atmosphere that are normally locked into the structure of the solid coal.

c They are further outside of the protective atmospheric layers of the Earth so less radiation is absorbed before reaching them. The atmosphere becomes less dense the higher you go, so the shielding effect the atmosphere has on the incident radiation is less.

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d

Type of radiation	Description	Name three types	Name one source for each
Ionising	This is a particle or electromagnetic radiation with enough energy per particle of photon to remove electrons from an atom or molecule and produce an ion.	alpha particles	nuclear decay
		beta particles	nuclear decay
		gamma rays	cosmos—hottest objects such as neutron stars, pulsars and black holes
		X-rays	cosmic radiation or X-ray machines
		high-frequency ultraviolet	solar radiation and electric arcs
Non-ionising	This is electromagnetic radiation with insufficient energy per photon to ionise an atom or molecule.	low-frequency radio waves	starlight two-way radio, TV and radio stations
		microwaves	mobile phones, microwave ovens
		infrared	any object emitting heat (above zero K)
		visible light	Sun, gas discharge tubes, light bulbs, LEDs
		low-frequency ultraviolet	Sun

e **i** $^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + {}^{4}_{2}\text{He}$

$^{234}_{90}\text{Th} \rightarrow {}^{234}_{91}\text{Pa} + {}^{0}_{-1}\text{e}$

$^{234}_{91}\text{Pa} \rightarrow {}^{234}_{92}\text{U} + {}^{0}_{-1}\text{e}$

ii $^{234}_{92}\text{U} \rightarrow {}^{222}_{86}\text{U} + 3\,{}^{4}_{2}\text{He}$

f In any uranium mine radon gas must be present. Therefore it would be safer for workers in an open cut mine as this gas would be able to escape more readily.

g Bore water comes up from underground where it has been in contact with rock containing uranium that decays to release radon. The radon will be dissolved in the water under pressure and released when the water comes to the surface. If the water is heated the radon will be less soluble and come out of solution more readily.

h dose $= 5 \times 30 \times (3.7 \times 10^{-6})$

$= 5.55 \times 10^{-4}$ Sv

i **i** $^{14}_{6}\text{C} \rightarrow {}^{14}_{7}\text{N} + {}^{0}_{-1}\text{e}$

ii $^{1}_{0}\text{n} \rightarrow {}^{1}_{1}\text{H} + {}^{0}_{-1}\text{e}$

iii Carbon dating relies on measuring the concentration of carbon-14 atoms relative to the total carbon in a fossil. The basis of this is that the total carbon in the fossil will remain constant but the concentration of carbon-14 will decrease as the fossil ages, due to its decay. Knowing the half-life and relative amount of carbon-14 present at any time enables the age of the fossil to be determined.

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