

Contents

	<i>Page no.</i>
P3 Radioactive materials – Foundation Workbook answers	P3-F2
P3 Radioactive materials – Higher Workbook answers	P3-F7

Further guidance

P3 Radioactive materials – Foundation Workbook answers

1	a	i	Heating water using a gas boiler
		ii	Gas boiler 20%, electric immersion heater 52%
		iii	At the power station
	b	i	Electricity
		ii	Electricity is made from another (primary) energy source
	c		It is convenient – comes on at the flick of a switch. It can easily be transmitted over long distances. It can be used by a wide variety of devices.
	d		Correct bold words: increasing, generate, winter's, blackouts, fossil, carbon dioxide, 'greenhouse', climate
2	a		<ul style="list-style-type: none"> Natural sources: radon in air, from rocks, cosmic rays from where she lives, cosmic rays from air travel, from food and drink Artificial sources: from medical treatments, from nuclear industry and fallout
	b		Natural sources 1.28 mSv, artificial sources 0.057 mSv
	c		A small increase
	d		Less than the national average
	e		Much less than 3%
	f		For example: <ul style="list-style-type: none"> miners – from rocks and buildings air crew and frequent fliers – cosmic rays from air travel medical staff using radioactive materials – from medical treatments some workers in nuclear industry – from nuclear industry and fallout
3	a		Correct bold words: alpha, most, bigger, short, easily, small, contamination
	b		The radon builds up in an enclosed area. People → breathe in atoms of the gas, which might → give off alpha radiation inside a person's lungs. The alpha particles → are absorbed by soft, internal tissue. They can → ionize atoms in cells; this can → damage the cells or cause a cancer.
	c		<ul style="list-style-type: none"> Irradiation: dose from radioactive materials in cloud, rain washing radioactive materials out of the air, dose from radioactive materials deposited on the ground Contamination: dose from radioactive materials in the air, dose from eating and drinking radioactive materials in food, dose from breathing in sea spray and sand

Further guidance

4	a		<table border="1"> <thead> <tr> <th>Type of radiation</th> <th>Is absorbed by a thin sheet of paper</th> <th>Is absorbed by a thin sheet of aluminium</th> <th>Is absorbed by a thick sheet of lead</th> </tr> </thead> <tbody> <tr> <td>alpha</td> <td>✓</td> <td>✓</td> <td>✓</td> </tr> <tr> <td>beta</td> <td>✗</td> <td>✓</td> <td>✓</td> </tr> <tr> <td>gamma</td> <td>✗</td> <td>✗</td> <td>✓</td> </tr> </tbody> </table>	Type of radiation	Is absorbed by a thin sheet of paper	Is absorbed by a thin sheet of aluminium	Is absorbed by a thick sheet of lead	alpha	✓	✓	✓	beta	✗	✓	✓	gamma	✗	✗	✓
		Type of radiation	Is absorbed by a thin sheet of paper	Is absorbed by a thin sheet of aluminium	Is absorbed by a thick sheet of lead														
		alpha	✓	✓	✓														
		beta	✗	✓	✓														
gamma	✗	✗	✓																
b	<ul style="list-style-type: none"> • X-ray → Passes through soft tissue and is absorbed by dense tissue. It can be controlled and directed by the machine that makes it. → Taking photographs of internal structures like bones • Beta radiation → Is absorbed by cells and can kill them. → Treating cancers by killing the cancerous cells • Gamma radiation → Penetrates tissue easily and is given out by the nuclei of atoms which can be injected into the body. → Providing images of organs to look for abnormal function 																		
c	Correct bold words: medical, cells, cancer, small, benefits																		
d	i	Student's opinion. Suggested answers: You are feeling tired...																	
	ii	Student's opinion. Suggested answer: risk																	
5	a	<ul style="list-style-type: none"> • Wear gloves and an apron – to prevent clothes and skin being contaminated with sources of ionizing radiation • Wear protective clothing and stand behind a screen – to block out the radiation and reduce the dose and risk due to irradiation • Wear a special badge that is sensitive to ionizing radiation – to monitor the radiation dose over a year 																	
		b	i	<table border="1"> <thead> <tr> <th></th> <th>alpha</th> <th>beta</th> <th>gamma</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>✓</td> <td>✓</td> <td>✓</td> </tr> <tr> <td>B</td> <td></td> <td>✓</td> <td>✓</td> </tr> <tr> <td>C</td> <td></td> <td></td> <td>✓</td> </tr> </tbody> </table>		alpha	beta	gamma	A	✓	✓	✓	B		✓	✓	C		
	alpha	beta	gamma																
A	✓	✓	✓																
B		✓	✓																
C			✓																
		ii	Hospital radiologist, scientist in a nuclear power station, technician who sterilizes surgical equipment with gamma rays																
	c		<p>Radiologist – This is an example of trying to keep risk as low as possible.</p> <p>Policewoman – This is an example of the idea that nothing can ever be completely safe.</p> <p>Doctor – This is an example of balancing the benefits against the risks.</p> <p>Patient – This is because the risk depends on the total radiation dose you have received.</p> <p>Airline pilot – This is an example of a new technology presenting a new risk.</p>																

Further guidance

	d	i	Benefits: see the world, enjoy holidays in the sun/faraway places, wider business/study opportunities, visit family and friends, etc.
		ii	Additional risks: air accidents, etc.
		iii	The risks are relatively low / benefits outweigh the risks
6	a	i	<ul style="list-style-type: none"> • Coal – contains some C-12 atoms; black and crumbly; contains some C-11 atoms; is slightly radioactive • Diamond – very hard, transparent, and sparkly; contains some C-12 atoms; contains some C-11 atoms; is slightly radioactive • Cellulose – contains some C-12 atoms; contains some C-11 atoms; part of the structure of plant cells; is lightly radioactive • Carbon dioxide – contains some C-12 atoms; colourless gas; contains some C-11 atoms; is slightly radioactive
		ii	Contains some C-12 atoms; contains some C-11 atoms; is slightly radioactive
		iii	Correct bold words: different, chemical, element, is not
	b	i	Electrons
		ii	Nucleus
		iii	Protons
7	a		Correct bold words: tracers, water, monitored, soluble, gamma, penetrates
	b		<ul style="list-style-type: none"> • Following the route of cooling water... – Put iridium-131 into the water... • Killing cancer cells in a patient's thyroid gland – Inject the patient with ... • Doctors need a method of getting an image... – Give a patient a 'barium meal'... • Sterilizing surgical instruments... – Expose them to high intensity gamma... • Sterilizing food – Put the food in a sealed bag... • Looking for a leak in an underground pipe – Put some iridium-131 in the water...
	c	i	Correct bold words: pulp, more, machine, reduce
		ii	Beta
		iii	Beta radiation penetrates paper and is more ionizing than gamma radiation.
	d		Normally there is no smoke in the detector. The alpha radiation → ionizes air in a small chamber. The ions → carry a current in the chamber and the alarm is kept off. → If some smoke gets in the chamber, it → stops some of the alpha radiation so the detector's signal → changes and that sets off the alarm.
8	a		Missing words: boiler, turbine, generator, transformer

Further guidance

	b	<ul style="list-style-type: none"> • Nuclear fuel – is made into fuel rods which get extremely hot • Fossil fuel (coal, gas, or oil) – is burnt at very high temperatures in a furnace • Generator – produces a voltage when its shaft is spun round • Transformer – changes a low voltage into a higher voltage • Turbines – are driven round by the high-pressure steam • Boiler – turns water into high-pressure steam 												
	c	<p>The table should be left with the following:</p> <table border="1"> <thead> <tr> <th></th> <th>Fossil fuel power stations</th> <th>Nuclear power stations</th> </tr> </thead> <tbody> <tr> <td>The power stations produce...</td> <td>carbon dioxide waste</td> <td>radioactive waste</td> </tr> <tr> <td>This waste...</td> <td>contributes to global warming</td> <td>is hazardous for thousands of years</td> </tr> <tr> <td>People living near the power stations are...</td> <td>sometimes exposed to other pollutants</td> <td>at risk of catastrophic accidents</td> </tr> </tbody> </table>		Fossil fuel power stations	Nuclear power stations	The power stations produce...	carbon dioxide waste	radioactive waste	This waste...	contributes to global warming	is hazardous for thousands of years	People living near the power stations are...	sometimes exposed to other pollutants	at risk of catastrophic accidents
	Fossil fuel power stations	Nuclear power stations												
The power stations produce...	carbon dioxide waste	radioactive waste												
This waste...	contributes to global warming	is hazardous for thousands of years												
People living near the power stations are...	sometimes exposed to other pollutants	at risk of catastrophic accidents												
	d	<p>i Correct bold words: similar, heat, steam, blades, shaft, generator, voltage, transformer, National Grid</p> <p>ii Fuels rods / furnace and boiler</p> <p>iii</p> <ul style="list-style-type: none"> • Nuclear fuel: produces radioactive isotopes of new elements; nuclear reaction; changes the nucleus inside an atom; enriched uranium • Fossil fuel (coal, gas, or oil): chemical reaction; changes the bonds between atoms, combustion; produces new compounds – including pollutants 												
9	a	Correct bold words: radioactive, decreases, by a half, can, longer												
	b	<p>i C</p> <p>ii No</p>												
	c	<p>A: 0, 8, 16, 24</p> <p>B: 0, 15.7, 31.4, 47.1</p>												
	d	The half life; the background count												
10	a	<ul style="list-style-type: none"> • LLW – Made up of used protective clothing...– It is very bulky... • ILW – Made up of materials from inside the reactor...– It is chopped up and mixed... • HLW – Made up of the most dangerous fission products...– It is not very bulky but... 												
	b	Missing words: hazardous, absorbed, irradiation, contamination, food												
11	a	Life Cycle Assessment												
	b	£440 million + £700 million = £1140 million												
	c	Cradle (building) → use (running) → grave (decommissioning)												

Further guidance

	d	Cost: £3000 million, £1140 million, £3900 million																																												
	e	Decommissioning																																												
	f	£3000 million + £1140 million + £3900 million = £8040 million																																												
	g	Full costs include building, running and decommissioning.																																												
12	a	i Wind farm																																												
		ii Building and decommissioning costs are smaller.																																												
		iii Wind is intermittent (does not always blow).																																												
	b	<table border="1"> <thead> <tr> <th></th> <th>Wind farm</th> <th>Gas</th> <th>Nuclear</th> </tr> </thead> <tbody> <tr> <td>It takes ten years to build...</td> <td></td> <td></td> <td>✓</td> </tr> <tr> <td>It requires a large area...</td> <td>✓</td> <td></td> <td></td> </tr> <tr> <td>It is built of concrete...</td> <td>✓</td> <td>✓</td> <td>✓</td> </tr> <tr> <td>The energy source is free...</td> <td>✓</td> <td></td> <td></td> </tr> <tr> <td>0.19 kg of carbon dioxide...</td> <td></td> <td>✓</td> <td></td> </tr> <tr> <td>The supply cannot be guaranteed...</td> <td>✓</td> <td></td> <td></td> </tr> <tr> <td>The energy source is likely to...</td> <td></td> <td>✓</td> <td></td> </tr> <tr> <td>It produces a guaranteed constant...</td> <td></td> <td></td> <td>✓</td> </tr> <tr> <td>Decommissioning is a long...</td> <td></td> <td></td> <td>✓</td> </tr> <tr> <td>The structures can be dismantled...</td> <td>✓</td> <td>✓</td> <td></td> </tr> </tbody> </table>		Wind farm	Gas	Nuclear	It takes ten years to build...			✓	It requires a large area...	✓			It is built of concrete...	✓	✓	✓	The energy source is free...	✓			0.19 kg of carbon dioxide...		✓		The supply cannot be guaranteed...	✓			The energy source is likely to...		✓		It produces a guaranteed constant...			✓	Decommissioning is a long...			✓	The structures can be dismantled...	✓	✓	
	Wind farm	Gas	Nuclear																																											
It takes ten years to build...			✓																																											
It requires a large area...	✓																																													
It is built of concrete...	✓	✓	✓																																											
The energy source is free...	✓																																													
0.19 kg of carbon dioxide...		✓																																												
The supply cannot be guaranteed...	✓																																													
The energy source is likely to...		✓																																												
It produces a guaranteed constant...			✓																																											
Decommissioning is a long...			✓																																											
The structures can be dismantled...	✓	✓																																												

Further guidance

P3 Radioactive materials – Higher Workbook answers

1	a	i	Heating water using a gas boiler
		ii	Gas boiler 20%, electric immersion heater 52%
		iii	At the power station
	b	i	Electricity
		ii	Electricity is made from another (primary) energy source
	c		It is convenient – comes on at the flick of a switch. It can easily be transmitted over long distances. It can be used by a wide variety of devices.
	d		Correct bold words: increasing, generate, winter's, blackouts, fossil, carbon dioxide, 'greenhouse', climate
2	a		<ul style="list-style-type: none"> Natural sources: radon in air, from rocks, cosmic rays from where she lives, cosmic rays from air travel, from food and drink Artificial sources: from medical treatments, from nuclear industry and fallout
	b		Natural sources 1.28 mSv, artificial sources 0.057 mSv
	c		A small increase
	d		Less than the national average
	e		Much less than 3%
	f		For example: <ul style="list-style-type: none"> miners – from rocks and buildings air crew and frequent fliers – cosmic rays from air travel medical staff using radioactive materials – from medical treatments some workers in nuclear industry – from nuclear industry and fallout
3	a		Correct bold words: alpha, most, bigger, short, easily, small, contamination
	b		The radon builds up in an enclosed area. People → breathe in atoms of the gas, which might → give off alpha radiation inside a person's lungs. The alpha particles → are absorbed by soft, internal tissue. They can → ionize atoms in cells; this can → damage the cells or cause a cancer.
	c		<ul style="list-style-type: none"> Irradiation: dose from radioactive materials in cloud, rain washing radioactive materials out of the air, dose from radioactive materials deposited on the ground Contamination: dose from radioactive materials in the air, dose from eating and drinking radioactive materials in food, dose from breathing in sea spray and sand

Further guidance

4	a																			
		Type of radiation	Is absorbed by a thin sheet of paper	Is absorbed by a thin sheet of aluminium	Is absorbed by a thick sheet of lead															
		alpha	✓	✓	✓															
		beta	✗	✓	✓															
		gamma	✗	✗	✓															
	b	<ul style="list-style-type: none"> • X-ray → Passes through soft tissue and is absorbed by dense tissue. It can be controlled and directed by the machine that makes it. → Taking photographs of internal structures like bones • Beta radiation → Is absorbed by cells and can kill them. → Treating cancers by killing the cancerous cells • Gamma radiation → Penetrates tissue easily and is given out by the nuclei of atoms which can be injected into the body. → Providing images of organs to look for abnormal function 																		
	c	Correct bold words: medical, cells, cancer, small, benefits																		
	d	i	1800 euros																	
		ii	Uzbekistan cannot afford to use this technology.																	
5	a	<ul style="list-style-type: none"> • Wear gloves and an apron – to prevent clothes and skin being contaminated with sources of ionizing radiation • Wear protective clothing and stand behind a screen – to block out the radiation and reduce the dose and risk due to irradiation • Wear a special badge that is sensitive to ionizing radiation – to monitor the radiation dose over a year 																		
		b	i	<table border="1"> <thead> <tr> <th></th> <th>alpha</th> <th>beta</th> <th>gamma</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>✓</td> <td>✓</td> <td>✓</td> </tr> <tr> <td>B</td> <td></td> <td>✓</td> <td>✓</td> </tr> <tr> <td>C</td> <td></td> <td></td> <td>✓</td> </tr> </tbody> </table>				alpha	beta	gamma	A	✓	✓	✓	B		✓	✓	C	
	alpha	beta	gamma																	
A	✓	✓	✓																	
B		✓	✓																	
C			✓																	
		ii	Hospital radiologist, scientist in a nuclear power station, technician who sterilizes surgical equipment with gamma rays																	
	c	i	<p>Radiologist – This is an example of trying to keep risk as low as possible.</p> <p>Policewoman – This is an example of the idea that nothing can ever be completely safe.</p> <p>Doctor – This is an example of balancing the benefits against the risks.</p> <p>Patient – This is because the risk depends on the total radiation dose you have received.</p> <p>Airline pilot – This is an example of a new technology presenting a new risk.</p>																	

Further guidance

		ii	This is an example of the requirement to keep the risk as low as reasonably achievable.
		iii	<ul style="list-style-type: none"> • Radiation worker • Construction worker
		iv	Correct bold words: higher, consequence, worse, consequence
6	a	i	<ul style="list-style-type: none"> • Coal – contains some C-12 atoms; black and crumbly; contains some C-11 atoms; is slightly radioactive • Diamond – very hard, transparent, and sparkly; contains some C-12 atoms; contains some C-11 atoms; is slightly radioactive • Cellulose – contains some C-12 atoms; contains some C-11 atoms; part of the structure of plant cells; is slightly radioactive • Carbon dioxide – contains some C-12 atoms; colourless gas; contains some C-11 atoms; is slightly radioactive
		ii	Contains some C-12 atoms; contains some C-11 atoms; is slightly radioactive
		iii	Correct bold words: different, chemical, element, is not, nucleus, nucleus
	b	i	Outer layer labelled: electrons, negative charge Inner circle labelled: nucleus, contains neutrons, contains protons, positive charge
		ii	500 m
	c		<ul style="list-style-type: none"> • Neutrons: They are neutral – they have no charge. The number in the nucleus can vary for atoms of the same element. If there are too many or too few of these in the nucleus, then it may be unstable. • Protons: The number in the nucleus is always the same for atoms of a given element. They have a positive charge. The number in the nucleus equals the atomic number of the element.
	d	i	Ticks by the first and last atoms (both have 86 protons).
		ii	Atom Z would have 2 more protons. (The new atom has 84 protons, not 86.)
		iii	Arrow drawn from nucleus to alpha particle.
7	a		Correct bold words: pulp, more, machine, reduce
	b		It does not alter the food in terms of taste, texture, etc.
	c		Normally there is no smoke in the detector. The alpha radiation → ionizes air in a small chamber. The ions → carry a current in the chamber and the alarm is kept off. → If some smoke gets in the chamber, it → stops some of the alpha radiation so the detector's signal → changes and that sets off the alarm.
8	a		Missing words: boiler, turbine, generator, transformer

Further guidance

	b	<ul style="list-style-type: none"> • Nuclear fuel – is made into fuel rods which get extremely hot • Fossil fuel (coal, gas, or oil) – is burnt at very high temperatures in a furnace • Generator – produces a voltage when its shaft is spun round • Transformer – changes a low voltage into a higher voltage • Turbines – are driven round by the high-pressure steam • Boiler – turns water into high-pressure steam 												
	c	<p>The table should be left with the following:</p> <table border="1"> <thead> <tr> <th></th> <th>Fossil fuel power stations</th> <th>Nuclear power stations</th> </tr> </thead> <tbody> <tr> <td>The power stations produce...</td> <td>carbon dioxide waste</td> <td>radioactive waste</td> </tr> <tr> <td>This waste...</td> <td>contributes to global warming</td> <td>is hazardous for thousands of years</td> </tr> <tr> <td>People living near the power stations are...</td> <td>sometimes exposed to other pollutants</td> <td>at risk of catastrophic accidents</td> </tr> </tbody> </table>		Fossil fuel power stations	Nuclear power stations	The power stations produce...	carbon dioxide waste	radioactive waste	This waste...	contributes to global warming	is hazardous for thousands of years	People living near the power stations are...	sometimes exposed to other pollutants	at risk of catastrophic accidents
	Fossil fuel power stations	Nuclear power stations												
The power stations produce...	carbon dioxide waste	radioactive waste												
This waste...	contributes to global warming	is hazardous for thousands of years												
People living near the power stations are...	sometimes exposed to other pollutants	at risk of catastrophic accidents												
	d	<p>Correct bold words: nuclear, neutron, unstable, fission, releases (Note: part d not c)</p>												
	e	<p>A single neutron → is absorbed by a nucleus of uranium-235. This → makes the nucleus unstable. The nucleus → splits into two smaller nuclei. This fission reaction → releases energy and sends out → three more neutrons. Each of these → is absorbed by a nucleus of uranium-235. This → makes the nucleus unstable... (Note: part e not d)</p>												
	f	<p>Correctly coloured diagram and text. (The control rods are in the nuclear reactor. The coolant circulates between the reactor and the boiler. The water enters the coil in the boiler at the bottom, and exits as steam at the top.) (Note: part f not e)</p>												
	g	<p>Missing words:</p> <ul style="list-style-type: none"> • fission, chemical • chemical, fission • fission, chemical <p>(Note: part g not f)</p>												
9	a	<p>Correct bold words: radioactive, decreases, by a half, can, longer</p>												
	b	<p>A: 0, 8, 16, 24 B: 0, 15.7, 31.4, 47.1</p>												
	c	<p>i 8 days – 32g, 16 days – 16g, 24 days – 8g</p>												
		<p>ii 5 half-lives, 40 days</p>												
		<p>iii The half-life; the background count</p>												

Further guidance

10	a	<ul style="list-style-type: none"> • LLW – Made up of used protective clothing...– It is very bulky... • ILW – Made up of materials from inside the reactor...– It is chopped up and mixed... • HLW – Made up of the most dangerous fission products...– It is not very bulky but... 																																													
	b	Missing words: hazardous, absorbed, irradiation, contamination, food, safe, precautionary																																													
11	a	Life Cycle Assessment																																													
	b	£440 million + £700 million = £1140 million																																													
	c	Cradle (building) → use (running) → grave (decommissioning)																																													
	d	Cost: £3000 million, £1140 million, £3900 million																																													
	e	Decommissioning																																													
	f	£3000 million + £1140 million + £3900 million = £8040 million																																													
	g	Full costs include building, running and decommissioning.																																													
12	a	i	Wind farm																																												
		ii	Building and decommissioning costs are smaller.																																												
		iii	Wind is intermittent (does not always blow).																																												
	b	<table border="1"> <thead> <tr> <th></th> <th>Wind farm</th> <th>Gas</th> <th>Nuclear</th> </tr> </thead> <tbody> <tr> <td>It takes ten years to build...</td> <td></td> <td></td> <td>✓</td> </tr> <tr> <td>It requires a large area...</td> <td>✓</td> <td></td> <td></td> </tr> <tr> <td>It is built of concrete...</td> <td>✓</td> <td>✓</td> <td>✓</td> </tr> <tr> <td>The energy source is free...</td> <td>✓</td> <td></td> <td></td> </tr> <tr> <td>0.19 kg of carbon dioxide...</td> <td></td> <td>✓</td> <td></td> </tr> <tr> <td>The supply cannot be guaranteed...</td> <td>✓</td> <td></td> <td></td> </tr> <tr> <td>The energy source is likely to...</td> <td></td> <td>✓</td> <td></td> </tr> <tr> <td>It produces a guaranteed constant...</td> <td></td> <td></td> <td>✓</td> </tr> <tr> <td>Decommissioning is a long...</td> <td></td> <td></td> <td>✓</td> </tr> <tr> <td>The structures can be dismantled...</td> <td>✓</td> <td>✓</td> <td></td> </tr> </tbody> </table>			Wind farm	Gas	Nuclear	It takes ten years to build...			✓	It requires a large area...	✓			It is built of concrete...	✓	✓	✓	The energy source is free...	✓			0.19 kg of carbon dioxide...		✓		The supply cannot be guaranteed...	✓			The energy source is likely to...		✓		It produces a guaranteed constant...			✓	Decommissioning is a long...			✓	The structures can be dismantled...	✓	✓	
	Wind farm	Gas	Nuclear																																												
It takes ten years to build...			✓																																												
It requires a large area...	✓																																														
It is built of concrete...	✓	✓	✓																																												
The energy source is free...	✓																																														
0.19 kg of carbon dioxide...		✓																																													
The supply cannot be guaranteed...	✓																																														
The energy source is likely to...		✓																																													
It produces a guaranteed constant...			✓																																												
Decommissioning is a long...			✓																																												
The structures can be dismantled...	✓	✓																																													
	c	Various answers are possible, but recommendation should be justified using (comparative) data.																																													