Occupational Health and Safety Practice: Radiation Protection Routes Levels 2, 3 and 4 (NVQ 3043/4)

Incorporating:
Guidance notes for assessors and candidates
Underpinning knowledge questions
Guidance on answers
Additional guidance on practical work

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Guidance Notes for Assessors

1 The role of the assessor is not just to assess the candidate's work when the candidate's portfolio is complete. The assessor must liaise closely with their allocated candidates, throughout the period in which they are studying towards the qualification.

2 The assessor's task begins immediately a candidate who has enrolled is assigned to his jurisdiction. From then on the assessor needs to be in direct contact with the candidate and involved with all aspects of the candidate's work. The assessor will act as guide and counsellor as well as formal assessor.

3 It is important that assessors are involved immediately with the candidate in drawing up an assessment plan. This process is a requirement for centre approval from City & Guilds.

4 It is important that the assessor is familiar with the candidate's area of work and its access limitations in so far as Regulations and local orders/instructions are concerned.

5 The assessor will appreciate the requirements of ALARA/ALARP and must not expect the candidate to pursue the task of evidence gathering where this is in contradiction of this principle. Other ways of gathering necessary evidence must be considered.

6 The bank of knowledge questions can be used in two ways either as oral questions or as written test questions. Many of the questions lend themselves to oral examination as it is then easier to probe the candidates real knowledge by asking supplementary questions and also provide clarification to candidates on aspects of a question they do not understand or the depth of the answer required. Questions may also be amended where they can be made more relevant to the candidate's working environment, though the underlying depth of the question must still satisfy the knowledge specification of the NVQ.

Assessors must not forget to make notes when asking oral questions in order to show whether or not the candidate has picked out the important facts required. It is permissible for assessors to rephrase whole questions, to amend the question to fit in with the candidate's working environment, to add or amend numerical values if the assessor considers this useful. Although guidance on answers is given, these should not be considered as model answers – assessors will be aware of the answers required at appropriate levels. Assessors should use the question bank as a supplement to evidence provided by practical work. It is important that the candidate sees them as an aid to demonstrating his/her knowledge.

7 The questions from the bank should not be used such that the candidate feels that he/she is sitting down to take a formal written examination. The questions are intended to supplement other methods of evidence gathering. For example a candidate may, in the course of his/her work, be required to assess the amount of radioactivity on an air sample paper. This activity requires the candidate to appreciate counting techniques, requirements for calibration, measurement units, counter efficiency, handling etc. and examples of practical work in this area are thus readily available. Some questioning by a mentor/assessor might also be appropriate during this activity as with other practical work.

8 The majority of questions in the bank are appropriate to all levels of the NVQs. The assessor must at all times bear in mind that the candidate is being assessed against the level of knowledge and understanding appropriate to the level of the NVQ being undertaken. This, of course, applies to all facets of the NVQs.

9 Legislation may be more appropriately dealt with by *oral* questioning at the discretion of the assessor as may knowledge concerning local rules, systems of work, working practices and methods of record keeping. Many of these facets of knowledge are better dealt with as they arise during normal work.

10 It is to be hoped that no real incidents of significance will arise. In general, however, the way in which small incidents and large incidents are dealt with involves similar thought processes; it is the level of response/control/reporting that changes. The participation in emergency-incident practices, however simple, is, it is hoped, the only practical demonstration of ability in this regard. However, supplemented by suitable questioning this is perfectly adequate. Exercises and exercise simulations and risk assessments are appropriate methods of covering the requirements of the NVQ.

11 These notes for guidance should be read in conjunction with the QCA guidance document 'Assessing NVQs' published in March 1998. QCA Ref: QCA/98/135. Copies of this document may be obtained by contacting QCA (The Qualifications and Curriculum Authority) Publications – PO Box 235, Hayes, Middlesex UB3 1HF (Tel: 020 8867 3333 or Fax: 020 8867 3233).

NVQ in Occupational Health and Safety Practice – Radiation Protection Support

Introduction to the Question Bank

This Question Bank is for use at all levels of the NVQ. The Knowledge Specification associated with the Standards gives the rating for the three levels of the award in terms of whether a *General Awareness (GA),* a *Basic Understanding (BU)* or a *Detailed Understanding (DU)* is required. These ratings may be described as follows:

General awareness – GA

Knows that the topic exists, can give an account of its content, and apply the knowledge in limited and defined circumstances. Knows who to go to or where to look for help if needed.

Basic understanding – BU

Has a basic understanding of the topic with a level of detail allowing application to a broad range of appropriate work activities in a variety of work contexts. If necessary can research further knowledge using readily available sources and apply it in familiar circumstances.

Detailed understanding – DU

Has a good understanding of the topic and the underlying principles, and can apply the knowledge in a broad range of complex technical situations in a variety of contexts. Can apply the knowledge, working from basic principles, to deal with situations in new or unfamiliar areas and can identify and control the peripheral and long term issues arising from its application.

An indication of the rating for each level is given against each question in the Question Bank that follows.

Underpinning knowledge question bank

		Rating		
		Level 4	**Level 3**	**Level 2**
Basic Physics				
BP1	Draw a diagram of a simple atom showing the three principal particles and indicate their electrical charge.	BU	BU	GA
BP2	State what changes occur in the nucleus of an atom when it undergoes alpha decay.	BU	BU	GA
BP3	Name the three principal particles that constitute the atom.	BU	BU	GA
BP4	What is radioactivity? What is the main difference between a radioactive substance and a non-radioactive substance?	BU	BU	GA
BP5	Name three of the particles/rays/photons that are generally considered to constitute a hazard in the field of radiation protection.	DU	BU	BU
BP6	State what changes occur in the nucleus of an atom when it undergoes beta decay.	BU	BU	GA
BP7	What is a beta particle?	DU	BU	BU
BP8	What is the inverse square law in relation to gamma radiation?	DU	BU	BU
BP9	Compare the ranges in air and in tissue of alpha particles, beta particles and gamma rays.	BU	GA	GA
BP10	Describe, in general terms, how beta and alpha particles react with matter to give up their energy.	BU	GA	GA
BP11	State, giving reasons, what materials should be used to shield a high activity source of high energy beta radiation.	BU	GA	GA
BP12	State, with reasons, what materials should be used to shield a source of high energy neutrons.	BU	GA	GA
BP13	State, with reasons, what materials should be used to shield a source of gamma rays.	BU	GA	GA
BP14	State, with reasons, what materials should be used to shield a mixed source of alpha, beta and gamma rays.	BU	GA	GA
BP15	State, with reasons, what materials should be used to shield a mixed source of gamma rays and neutrons.	BU	GA	GA
BP16	What materials might be used in shielding a diagnostic x-ray room?	DU	GA	BU
BP17	Describe, in general terms, how beta particles/alpha particles/ gamma photons/neutrons (fast and thermal) react with matter to give up their energy. (The questions should not require all parts to be answered but should be suitably amended to include only one of the particles/photons mentioned as considered appropriate).	BU	GA	GA
BP18	Describe, in general terms, the difference between the stochastic and deterministic effects of ionising radiation.	DU	BU	GA

		Rating		
		Level 4	**Level 3**	**Level 2**
BP19	State, in general terms, the difference between the somatic and genetic effects of ionising radiation.	DU	BU	GA
BP20	Describe, in general terms, the possible effects on the body of a high dose of external gamma radiation of about 5 sieverts, received over a period of a few hours.	DU	BU	GA
BP21	Describe, in general terms, the likely effects on the body of a high dose of beta radiation of about 15 sieverts, received over a period of a few hours.	DU	BU	GA
BP22	Describe, in general terms, how the likely effects on the body of a large dose of ionising radiation from external sources may vary, depending on whether the dose is received over a period of a few hours or a few months/years.	DU	BU	GA
BP23	Explain the difference between the gray and the sievert in relation to radiation protection.	BU	BU	GA
BP24	Define the unit of radioactivity.	BU	BU	GA
BP25	Explain the difference between Absorbed Dose, Equivalent Dose, Effective Dose, Committed Effective Dose, Collective Dose and Dose.	BU	BU	GA
BP26	State the dose limits that apply to an employee aged 18 years and over (ref IRR99). (This question may be asked in a number of different forms aimed at testing the individual's knowledge of dose limits).	BU	BU	GA
BP27	Define, in simple terms, bremsstrahlung radiation.	DU	BU	BU
BP28	What is the definition of the half-life of a radionuclide?	BU	GA	GA
BP29	Explain what is meant by a chain reaction in the process of nuclear fission.	BU	GA	GA
BP30	Explain what is meant by fission products.	BU	GA	GA
BP31	What is meant by the term 'criticality' in relation to fissile/ fissionable materials?	BU	GA	GA
BP32	State, with reasons, four factors which may affect the critical mass of a fissile material	BU	GA	GA
BP33	Explain, in simple terms, the difference between atomic number and mass number and state how these are normally denoted.	BU	BU	GA
BP34	Explain, in general terms, what somatic effects of radiation might be sustained by people after exposure to whole body radiation from external sources. The answer should be related to a wide range of exposures from occupational levels through to doses of 10 sieverts.	DU	BU	GA
BP35	Describe how x-rays can be used to detect flaws in the welded joints of pipes.	DU	BU	GA
BP36	Discuss the types and physical properties of ionising radiations.	DU	BU	GA
BP37	Discuss the interaction of ionising radiation with matter.	DU	BU	GA

		Rating Level 4	Level 3	Level 2
BP38	Discuss the biological effects of ionising radiation.	DU	BU	GA
BP39	What is the gamma factor of a source?	DU	GA	BU

Basis of radiological protection

		Level 4	Level 3	Level 2
BRP1	State some examples of the biological damage observed in people who worked with x-rays and radium during their discovery and soon afterwards.	GA	GA	GA
BRP2	Since the discovery of x-rays and radioactive materials, the use of these has developed into many fields. Discuss three examples of the uses of radioactive materials and radiation, which have had very significant effects on people's lives generally. (Atomic weapons, medical uses – diagnosis and therapy, civil nuclear power reactors.)	GA	GA	GA
BRP3	Apart from the people who worked with x-rays and radioactive materials, notably radium, in the early days after their discovery, there have been other groups of people who were exposed to high doses of radiation. The biological damage these groups sustained has been instrumental in helping to develop dose limits. Discuss some of these occurrences (Ankylosing spondylitis – exposed to very large doses of x-rays to the back, luminous dial painters, survivors of the atomic bombs dropped on Japan.)	BU	GA	GA
BRP4	Give examples of some of the major incidents which have occurred throughout the world indicating their significance, scale of damage and lessons learned. (Chernobyl, Three Mile Island, Windscale, Tokai Mura).	GA	GA	GA
BRP5	Discuss the roles of The National Radiological Protection Board and the International Commission on Radiological Protection in helping to set radiation dose limits for the United Kingdom.	GA	GA	GA
BRP6	Explain what is meant by the ALARA or ALARP principle.	DU	BU	BU
BRP7	State, with reasons, what facts should be considered when applying the ALARP principle to **one** of the following: a) the accumulation of radioactive waste b) entry to an area of relatively high radiation doserate to carry out maintenance work c) provision of a radioactive sealed source store d) work on a ventilation plant extracting and filtering air from a laboratory environment in which unsealed sources are handled	DU	BU	BU
	(The different parts of this question should be used or further modified in circumstances appropriate to the candidate's work.)			
BRP8	Discuss, in very simple terms, what is meant by the terms justification and optimisation.	DU	BU	GA
BRP9	List some of the general practices that should be considered when applying the ALARP principle.	DU	BU	BU

		Rating		
		Level 4	**Level 3**	**Level 2**
BRP10	Discuss, in simple terms, the stochastic and deterministic effects of radiation.	BU	GA	GA
BRP11	Discuss how the system of radiological protection utilises the principles of optimisation and justification in achieving its main objectives.	DU	BU	GA
BRP12	Discuss the general principles of ALARA/ALARP and give examples of how doses to individuals can be kept as low as reasonably practicable.	DU	BU	BU

Detection and Measurement of Radiation

DMR1	State three methods by which radiation can be detected.	BU	BU	BU
DMR2	Explain, in simple terms, how a scintillation probe can be used to detect and measure alpha radiation, and state some of its limitations.	BU	BU	BU
DMR3	Explain, in simple terms, how an ionisation chamber or Geiger Muller tube can be used to detect and measure beta radiation and state some of its limitations.	BU	BU	BU
DMR4	Describe, in simple terms, how thermal neutrons can be detected and measured.	BU	BU	BU
DMR5	Describe, in simple terms, how fast neutrons can be detected and measured.	BU	BU	BU
DMR6	Describe, in general terms, how a thermoluminescent dosemeter detects radiation and explain how a radiation dose can be established from this.	BU	BU	BU
DMR7	State the three main sources of natural background radiation.	BU	BU	BU
DMR8	Give an example of when and why background radiation must be taken into account when making measurements.	BU	BU	BU
DMR9	When counting air sample papers, why is it good practice to count for a long time, particularly if the count rate is low?	BU	BU	BU
DMR10	State, with reasons, what errors might be expected if an air sample paper was counted immediately after its removal from an air sampler.	BU	BU	BU
DMR11	State, with reasons, why sample papers should be handled with great care during and after removal from an air sampler.	BU	BU	BU
DMR12	State, with reasons, what points should be taken into account when deciding where to position an air sampler.	DU	BU	BU
DMR13	State, with reasons, some of the limitations associated with air sampling.	DU	BU	BU
DMR14	State, with reasons, why it is so important to ensure that instruments are properly calibrated.	BU	BU	GA
DMR15	What are the statutory requirements relating to instrument calibration?	BU	BU	GA

		Rating Level 4	Level 3	Level 2
DMR16	State, with reasons, what personal dosemeters should be worn by a person entering a controlled area to carry out maintenance work on contaminated equipment. Gamma doserates from the equipment vary between 20 and 200 μSv/h.	BU	GA	GA
DMR17	State, with reasons, some of the limitations associated with the use of personal air samplers.	DU	BU	BU
DMR18	State, with reasons, what biological monitoring might be advised if a person working in a contamination controlled area, wearing full contamination protective clothing, including an air fed plastic suit, were to cut him/herself on a piece of highly contaminated metal.	BU	GA	GA
DMR19	Give an example of how a standard type beta/gamma radiation survey meter might be calibrated to satisfy legal requirements.	BU	BU	GA
DMR20	Doses from radioactive materials taken into the body are difficult to measure. Give some examples of what monitoring and dose estimation can be done.	BU	GA	GA
DMR21	Explain what is meant by the ‘dead time’ of a Geiger Muller counter and state, with reasons, why this may need to be taken into account when making measurements.	BU	BU	BU
DMR22	Which type of detector is recommended for use in a contamination monitor designed for measuring a) beta particles and b) gamma rays, and why?	DU	GA	BU
DMR23	Describe a contamination monitor suitable for measuring iodine-125.	DU	GA	BU
DMR24	Describe the technique used for monitoring tritium contamination on laboratory benches.	DU	GA	BU
DMR25	How should a Nuclear Medicine flood source be leak tested?	DU	GA	BU
DMR26	What type of personal dose monitor should be worn by an x-ray radiographer?	DU	GA	BU
DMR27	Describe the limitations of using a film badge dosimeter for monitoring the whole body dose of a laboratory worker using unsealed sources.	DU	BU	GA
DMR28	What form of monitoring would you suggest for a cardiologist routinely performing angioplasty procedures?	GA	BU	BU

Legislation

This subject lends itself better to oral examination. Questions relating to legislation are generally difficult to couch in easily understood terms. In most circumstances the subject is better discussed between the assessor and candidate so that candidates can ask for clarification Supplementary questions can also be asked by the assessor to ensure that the candidate understands the question.

		Rating		
		Level 4	**Level 3**	**Level 2**
L1	What is the essential difference between a Regulation, an Approved Code of Practice and Notes of Guidance?	DU	BU	GA
L2	The Ionising Radiations Regulations 1999 require, in certain circumstances, the appointment and use of: Radiation Protection Advisers (RPA) Qualified Persons (QP) and Radiation Protection Supervisors (RPS) State briefly the function of each of these. (This question could easily be split into three parts)	DU	BU	GA
L3	In the context of issuing, reading and recording doses measured by personal dosemeters – can these functions be performed by anyone who has the proper equipment, systems etc? Give reasons for your answer.	DU	BU	GA
L4	State, with reasons what action should be taken if, during the year, a whole body dose of greater than 15mSv is recorded.	DU	BU	GA
L5	What factors should be taken into account when determining the frequency of leakage tests on sealed sources?	DU	BU	GA
L6	Give an example of the briefing that might be given to the driver of a vehicle carrying radioactive material from one part of the country to another.	BU	BU	GA
L7	a) What is a controlled area? b) What is a supervised area? c) In what circumstances can an employee or other person enter or remain in a controlled area without that person being a classified person?	DU	BU	GA
L8	In what circumstances must an employer designate employees as classified persons?	DU	BU	GA
L9	What are the functions of an Approved Dosimetry Service?	DU	BU	GA
L10	An employee has been exposed during an unforeseen occurrence to a dose of radiation likely to be in excess of 15 mSv to the whole body. What action must an employer take?	DU	BU	GA
L11	What is a health record? In what circumstances must it be maintained, and for how long must it be kept?	DU	BU	GA
L12	What do the Ionising Radiations Regulations require with respect to the accounting of radioactive substances?	DU	BU	GA
L13	What do the Ionising Radiations Regulations require of an employer in relation to the provision of monitoring equipment?	DU	BU	GA
L14	What requirements do the Ionising Radiations Regulations place on an employer in relation to the investigation and notification of an overexposure?	DU	BU	GA

		Rating		
		Level 4	**Level 3**	**Level 2**
L15	a) Specify the dose limits for the whole body, as laid down in the Ionising Radiations Regulations b) Specify the dose limits for skin and extremities, as laid down in the Ionising Radiations Regulations c) Specify the dose limits for the lens of the eye, as laid down in the Ionising Radiations Regulations d) Specify the dose limit for the abdomen of a woman of reproductive capacity, as laid down in the Ionising Radiations Regulations e) Specify the dose limit for the control of exposure to the foetus of a pregnant woman, as laid down in the Ionising Radiations Regulations.	DU	BU	GA
L16	What do the Ionising Radiations Regulations require of an employer concerning the designation of an area in relation to internal radiation?	DU	BU	GA
L17	What does the Radioactive Substances Act 1993 require in relation to the keeping and use of radioactive material and mobile radioactive apparatus?	BU	GA	GA
L18	Give an example of an exemption from registration under Section 7 of the Radioactive Substances Act 1993.	BU	GA	GA
L19	State the differences between Enforcement notices and Prohibition notices, in relation to the Radioactive Substances Act 1993.	BU	GA	GA
L20	What are the requirements of the Radioactive Substances Act 1993, in relation to a) the accumulation of radioactive waste; and b) the disposal of radioactive waste?	BU	GA	–
L21	State the differences between Improvement Notices and Prohibition Notices issued under the Health and Safety at Work etc. Act 1974 and explain their relevance to work with ionising radiation.	BU	GA	–

Control of Exposure

CE1	What are the differences between the internal and external hazards from radiation? Give reasons for your answer.	DU	BU	GA
CE2	Describe, with reasons, how time, distance and shielding can be used to limit or reduce doses of radiation to workers from external sources.	DU	BU	GA
CE3	What is the approximate dose in air at 2 metres from a cobalt-60 point source of 10GBq? Cobalt-60 gives off 2 gamma rays of 1.17MeV and 1.33MeV in 100% of its disintegrations. (Use of approximation formula 146 x sum of energies in MeV x source strength in GBq gives the doserate in μSv/h at 1 metre).	DU	BU	GA
CE4	State the criteria for the designation of Controlled and Supervised Areas – and describe the controls, both physical and administrative, appropriate for each.	DU	BU	BU

		Rating Level 4	Level 3	Level 2
CE5	Explain, with reasons, how a ventilation plant associated with a controlled area can help to limit dose to workers in the plant and to the general public. (In the answer it is important that the candidate identifies what monitoring needs to be carried out on the plant in order to validate its efficiency).	DU	BU	GA
CE6	Why is 'good housekeeping' considered to be one of the prerequisites for a safe environment?	DU	BU	BU
CE7	Why is it good practice to check frequently on radiation and contamination levels whilst carrying out tasks on plant or materials giving rise to these hazards? (This question should be appropriately modified so that it can relate to the candidate's working environment eg if the plant is associated with waste handling/disposal it should be couched in terms identified with this activity.)	DU	BU	BU
CE8	Describe the system of control and design features appropriate to an enclosure used for the radiography of components with both x-ray sets and highly radioactive sealed sources. (A sketch might help).	DU	BU	GA
CE9	Describe, giving reasons, what personal protective clothing and dosimetry might be specified for a person carrying out repair work on a piece of highly beta/gamma contaminated equipment in a controlled area where radiation levels are about 100 μSv/h.	DU	BU	BU
CE10	State, with reasons, what precautions should be taken when radiography is being undertaken on an open site.	DU	BU	GA
CE11	What action should be taken by a health physics monitor/surveyor/technician if a person reports finding significant contamination on shoes and hands at the exit barrier from a controlled area?	DU	BU	BU
CE12	What routine checks should be performed on glove boxes to ensure safe performance?	DU	BU	BU
CE13	How should air extracted from glove boxes used for handling radioactive materials be processed/monitored before discharge to the atmosphere?	DU	BU	GA
CE14	Describe three routes by which radioactive liquid effluent disposed of to the sea or inland waterway could become a hazard to humans.	DU	BU	GA
CE15	What precautions should be taken to ensure that discharges to the atmosphere are kept within authorised limits?	DU	BU	BU
CE16	State, with reasons, some examples of how radioactive waste arisings can be limited.	DU	BU	BU
CE17	Outline a scheme of good practice for handling waste arisings from the decontamination of large items.	DU	BU	BU
CE18	State, with reasons, what routine monitoring should be carried out around a nuclear reactor (a) when it is operating; and (b) when it is shut down for maintenance.	DU	BU	BU

		Rating		
		Level 4	**Level 3**	**Level 2**
CE19	State, with reasons, the different hazards that might need to be considered (a) when a reactor is operating; and (b) when it is shut down for maintenance.	DU	GA	GA
CE20	State the three main routes by which radioactive materials may enter the body and explain the precautions that might be taken in each case to guard against it.	DU	BU	GA
CE21	State, with reasons, what actions should be taken by the local radiological protection service if notified that the packaging around a radioactive consignment was found to be contaminated on receipt.	DU	BU	BU
CE22	Describe what actions should be taken if widespread contamination was found during the routine survey of an area in which unsealed radioactive substances were handled. (Alpha or beta contamination could be specified.)	DU	BU	BU
CE23	Describe what actions should be taken if contamination was found during the routine survey of an area in which sealed radioactive substances were handled.	DU	BU	BU
CE24	State, with reasons, three ways in which it may be possible to reduce doses to persons carrying out work in an area where the external gamma doserate in the area varies between 20 μSv/h and 100 μSv/h.	DU	BU	GA
CE25	State two advantages and two disadvantages of airline suits compared with respirators.	DU	BU	BU
CE26	State two circumstances in which respirators will give a person totally inadequate protection.	DU	BU	BU
CE27	What is the importance of particle size and solubility with respect to the inhalation of radioactive airborne particulate activity?	DU	BU	GA
CE28	Describe, with reasons, how a 300 GBq sealed source contained in an adequately shielded radiographic source container might be leak tested to satisfy statutory requirements? The container is fitted with a mechanism that allows the source to be wound out into a tube for radiographic purposes.	DU	BU	GA
CE29	Give two examples of the need to carry out smear/swab monitoring rather than direct monitoring with a probe.	DU	BU	BU
CE30	Give examples of the local rules relating to workplace monitoring in your area of work.	DU	BU	BU
CE31	State the basic requirements of any contingency plan in relation to your place of work. Particular emphasis should be given to monitoring requirements and methods, site related and off-site related; instruments used; assessment methods; reporting systems; limits; decision levels; and involvement of outside agencies.	BU	GA	GA

		Rating		
		Level 4	**Level 3**	**Level 2**
CE32	What would constitute a controlled area when radiography is being undertaken with a mobile device on the wards?	DU	GA	BU
CE33	Describe the radiation features you would expect to find in a laboratory using small quantities (<37 MBq) phosphorous-32 and sulphur-35.	DU	GA	BU
CE34	How should radioactive aqueous liquid waste be disposed from a laboratory using small quantities of unsealed sources?	DU	GA	GA
CE35	Describe the radiation protection features in and around a room housing a medical linear accelerator.	DU	GA	BU
CE36	Describe how the sources in a Selectron afterloading system might be leak tested.	DU	GA	BU
CE37	Describe the process of x-radiography.	DU	GA	BU

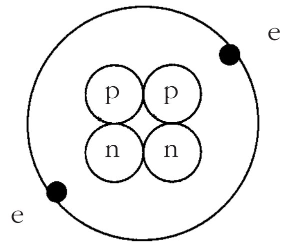
Guidance on answers to questions in question bank

Introduction

It is emphasised that these are **not** model answers. They cover the main points required in the answers. Assessors must judge whether answers are acceptable according to the rating of the question for each level of the NVQ.

Basic Physics

BP1



e = electrons: negative charge

p = protons: positive charge

n = neutron: neutral or no charge

BP2 When an atom undergoes alpha decay the nucleus loses 2 protons and 2 neutrons.

BP3 Electron, proton, neutron.

BP4 Radioactivity is the phenomenon by which an unstable nucleus becomes stable resulting from changes in nuclear configuration and changes in the proton/neutron content of the nucleus. Another answer could be: Radioactivity is the term used to describe the spontaneous disintegration of certain atoms into other forms, with the emission of radiations. Non-radioactive substances do not display this phenomenon.

BP5 Alpha particles, beta particles, gamma rays, neutrons.

BP6 A neutron in the nucleus changes to a proton and an electron which is ejected from the nucleus at high speed. (For level 3/4 – it would be expected that a candidate would also understand the term positron. By suitably amending the question it should be possible to obtain a more detailed answer relating to atoms with neutron deficiency or neutron excess.)

BP7 A beta particle is the name given to an electron ejected from the nucleus during radioactive decay. It is produced by a neutron changing to a proton and an electron. This electron is ejected at high speed from the nucleus.

BP8 The exposure measured from a point source of gamma radiation reduces in proportion to the inverse square of the distance from the source, ie a doserate measured at 3 metres will be $\frac{1}{3}^{2}$ of the doserate measured at 1 metre. Remember that as a source is approached the doserate will increase very rapidly – hence do not handle sources – even very low activity sources.

BP9

Range in air	Range in tissue
Alpha – 2-3 cms	generally less than the top dead layer of the skin and thus not considered an external radiation risk
Beta – 2-3 metres (but very energy dependent and may be as little as 1 cm for very low energy emitters)	up to about 1cm in soft tissue, but very energy dependent
Gamma – hundreds of metres	the whole thickness of the body plus

Gamma rays are not charged in the same way as alpha and beta particles and therefore lose energy in a totally different way. Whereas definite thicknesses of material will completely stop alpha or beta particles, gamma radiation is only attenuated dependent on the intensity and the absorption coefficient of the material through which it is passing.

BP10 Alpha particles and beta particles lose energy by either atomic or molecular excitation or ionisation. With atomic or molecular excitation subsequent de-excitation results in the emission of light. Ionisation involves the ejection of electrons from atoms. On average the energy expended in producing one ion pair in air due to excitation and ionisation is 34eV.

BP11 Materials of a low Z number, backed up if necessary by a material of a high Z number.

Reason. Beta particles produce electromagnetic radiation when stopped in matter: the higher the Z number the more electromagnetic radiation – 'Bremsstrahlung' : this is x-radiation and may be up to the energy of the beta particle. This will require materials of a high Z number to attenuate it. By using materials of a low Z number as a first shield, eg. aluminium, the thickness of a high Z number material, eg lead, to attenuate the electromagnetic radiation will be much less, thus the shielding required will weigh very much less.

BP12 Fast neutrons need to be shielded with hydrogenous material eg polythene, water, paraffin wax, to slow the neutrons down and then a neutron absorbing material to absorb the resulting thermal neutrons eg boron and cadmium. (Level 3/4 may be expected to expand this answer, especially if the question were differently and appropriately worded. One might expect some reference to resonance capture, capture cross-sections, etc.)

BP13 Gamma sources need to be shielded with materials of high Z number. Gamma rays are attenuated according to their energy and the absorption coefficient of the material. In general this coefficient is higher with higher Z numbers. (For level 3/4 one might expect reference to a formula, absorption coefficients, narrow and broad beam geometry and mention of the ways in which gamma photons lose energy – photoelectric effect, compton scattering and pair production.

BP14 Low Z number materials backed up by high Z number materials. Similar reasons to Qn BP11. Alpha particles will be stopped almost instantaneously by either of these materials.

BP15 Hydrogenous materials backed up by high Z number materials, together with some neutron absorbing material between the two or impregnated in them. Similar reasons to Qns BP12 and BP13.

BP16 Walls: of solid brick construction with barium plaster. In modern buildings, walls may be shielded with lead ply. 2 mm is usually sufficient for shielding from the primary beam.
Doors: lead lined. Thickness of between 1.5 and 2 mm. Care required to prevent leakage at joints and closure of double doors.
Control panel: usually shielded to 2.5 mm lead. Lower part, lead ply. Upper (glazed) section of lead glass.

BP17 Alpha/beta particles – Atomic or molecular excitation or ionisation. Charged particles are stopped by their encounters with hundreds of thousands of atoms. As they collide with each atom they will lose energy. The length of their track in a given material will be related to their energy. Gamma photons lose energy in three ways:

(a) Photoelectric absorption in which low energy protons transfer all their energy to an inner shell atomic electron and disappear in the process. The inner shell electron is ejected at high speed.

(b) Compton scattering – when the proton loses some of its energy by colliding with outer shell electron – which is knocked off at high speed (behaves like a particle).

(c) Pair production – which occurs when gamma rays of energy greater than 1.02 MeV come into the proximity of a nucleus and become a positive and a negative electron – both of which have high velocities.

(This answer should be expected from level 3/4 but not in so much detail for level 2.)

Neutrons – divided into fast and thermal. Fast give up their energy by elastic or inelastic scattering or capture by the nucleus of some radionuclides. Slow neutrons are absorbed. (For a level 4 answer this could be extended to mention fast fission/thermal fission – resonance capture, capture makes the capturing atom unstable.)

BP18 Stochastic effects are those in which the concept of no-threshold applies – the severity is independent of the dose, but the probability of the effects is proportional to the dose – no-threshold. With deterministic effects the biological effect increases in severity with increasing dose. In this case a threshold dose is evident below which no effect will be seen (see Qn BP38). [Level 4 would be expected to answer this question in more detail than Level 3 – (ICRP 60 – Nov 1990)]

BP19 Somatic effects are observed in the person irradiated. Genetic effects are those that are observed in descendants. (Level 3/4 would require a more detailed answer. The question should be altered to require reasons – damage to chromosomes/genes which are repairable – some irreparable, damage to genes, probability of affecting offspring.) (Do not forget that a foetus in the womb at the time of irradiation is not a descendant in this context.)

BP20 Within a few hours after receiving the dose it would be expected that a person would begin to feel ill – would develop sickness and diarrhoea and within days/a few weeks – unless treatment were afforded – would get progressively worse and have a 50% probability of death. (Level 2 will require a very basic understanding, Level 3 more than Level 2 and Level 4 more than Level 3. See also answer to BP22 – and do not forget to mention the importance of aftercare in keeping people alive).

BP21 Beta radiation – external to the body will penetrate only at most the top centimetre of tissue, therefore damage to skin most significant. Skin will redden over a period of hours/days – loss of hair likely. Skin likely to blister/peel, possibility of ulceration. Time taken for effects to be apparent will vary from individual to individual. If local to a small area there will be little ultimate effect. If over a large part of the body – similar to problems from conventional burns but taking longer to become apparent and heal.

BP22 (Much of this is level 3/4.) (a) Some cells of the body are more radiosensitive than others, if the dose is received over a short period, these cells (or many of them) may die. The repair mechanisms of the body may not function fast enough to make good losses before deleterious effects are observed. If the dose is spread over a long period of time then repair mechanisms may make good loss of cells, eg blood/skin before the loss is sufficient to have an observable effect. The lining of the gastro-intestinal tract which is in effect a very sophisticated filter is a good example of the way in which the body can repair itself. A large dose in a short time may cause sufficient damage to allow harmful products into the blood stream causing typical gastro enteritis symptoms. The same dose over a long period could give no noticeable effect because of the body's ability to repair itself. Some cells of the body do not replace themselves so quickly eg bone/muscle – but generally, cells that take longer to replace are generally less sensitive to radiation. Nerve cells are considered irreparable but the dose required to kill them is huge and would certainly cause death from other reasons (simple answers for Level 2)

BP23 (Level 3/4 answer would need more detail.) The gray is the unit of absorbed dose: the sievert is a unit which takes into account the fact that the same quantity of different radiations has differing effects on the body. Thus the sievert is the gray multiplied by a weighting factor which takes account of this differing damage. Other modifying factors may also be applied. The sievert is the unit related to damage (for level 3/4 – would expect reference to the gray = the energy absorbed per unit mass, and its unit as the joule per kilogram and the sievert as the unit of dose quantity 'equivalent dose' also expressed in joules per kilogram). At Level 4, it should be expected that candidates understand that effective dose is also measured in sieverts and that the reason the sievert unit is also Joules per kilogram is because weighting factors are dimensionless numbers.

BP24 The unit of radioactivity is the becquerel and is equal to a disintegration rate of 1 disintegration per second.

BP25 (Level 4, for levels 2 and 3 the answer should be modified accordingly)
Absorbed dose is a measure of the energy absorbed in an organ and is usually measured in grays.

Equivalent Dose is the Absorbed Dose averaged over an organ or tissue and multiplied by a radiation weighting factor to give a measure of the biological implications of the radiation exposure. The unit of Equivalent Dose is the sievert.

Effective Dose is the Equivalent Dose multiplied by an organ weighting factor to give a measure of the combined effect on the whole body of the doses to several different organs. The unit of Effective Dose is the sievert.

Committed Effective Dose is the sum over time of Effective Dose. It is used to assess the whole risk resulting from a single intake of a radioactive material. Normally the time interval is 50 years. For example, an intake of plutonium will result in plutonium remaining in the body for many years, gradually getting less. Each year that the plutonium is present, the body will receive an Effective Dose. The Committed Effective Dose is the calculated sum of the Effective Doses received by the body each year, over the fifty years following the intake. This Committed Effective Dose is then entered into the person's Dose Record for the year the intake took place and compared to the Annual Statutory Dose Limit for Effective Dose (20 mSv in IRR99). The unit of Committed Effective Dose is the sievert.

Collective Dose is the sum of Effective Doses, or Committed Effective Doses for a group of people. It is used in operational radiation protection for managing the radiation exposures for a group of people carrying out a large project ie for dose budgeting. The unit of Collective Dose is the person-sievert.

Dose is shorthand for any of the above, but usually means Effective Dose.

BP26 The answer to this question can be found in the IRR99 – Schedule 4.

BP27 'Bremsstrahlung' radiation is the name given to the electromagnetic radiation given off when beta particles are slowed down when passing through matter if they encounter a nucleus in their path – its energy may be up to the maximum energy of the beta particle.

BP28 The half life of a radionuclide is defined as the time taken for the radioactivity of the radionuclide to decay to half of its original value.

BP29 A chain reaction occurs when the neutrons released after fission cause at least one more fission the neutrons from which go on to cause at least one more fission, etc.

BP30 Fission products are the products of fission – these include the new isotopes produced, the energy released and the neutrons released.

BP31 Criticality is the name given to the process of fission in which the neutrons released during the fission process cause fission in other fissile or fissionable atoms. If the neutron population decreases in successive generations the system is said to be sub-critical. If, in successive generations, the neutron population remains constant, the system is said to be critical. If, in successive generations, the neutron population increases, the system is said to be super-critical.

BP32 Shape, moderation, reflection, interaction with other systems in the vicinity/with aqueous solutions addition of, or evaporation of solvents, enrichment, increase density/mass. Reasons must reflect rating for Level 2, 3, 4.

BP33 The atomic number (Z) of an element is equal to the number of protons in the nucleus of an atom. The mass number (A) is the number of nucleons (protons and neutrons) in the nucleus of an atom.

BP34 See questions BP18 to BP20, Occupational levels, no visible effects, etc.

BP35 X-rays will darken photographic film placed on one side of the welded pipe when x-rays are directed through the welded pipe towards the film. Any flaws ie holes where weld has not taken will attenuate the x-rays less than where the weld is complete. This will show as darker patches on the film indicating lower densities in these areas.

BP36 Include mention of directly and indirectly ionising radiations and secondary charged particles. Some information about pair production, photoelectric effect and Compton effect should also be included.

BP37 Include mention of elastic and inelastic scattering, random nature of the interactions, transfer of energy, LET, high LET, low LET.

BP38 Should include mention of stochastic and deterministic effects: cell death – the 'killing' of somatic cells consequent to irreparable damage to vital cell structures. Should mention the fact that rapidly dividing cells are likely to manifest cell death in a few hours or days after exposure, whereas in slowly dividing cell populations this may take months or years. For Level 4, one would expect answers to include mention of impairment of a function of an organ – if enough cells are killed – or indeed it may die. Some mention of cell modification/cancer, genetic damage – how it occurs and hereditary effects, should also be included at Level 4.

BP39 The specific gamma ray constant, which is the doserate at 1m from a point source in $\mu Sv\ h^{-1} MBq^{-1}$.

Basis of Radiological Protection

BRP1 Radiation burns to skin, skin dermatitis, soreness of eyes, sickness and diarrhoea, tumours. These from x-ray workers. Damage from radium after its discovery first showed in low white cell counts at the London Radium Institute. The luminising industry used small quantities of radium in zinc sulphate – by 'pointing' their brushes with their lips whilst painting, small quantities of radium were ingested – bone sarcoma was found after a long latent period.

BRP2 Atomic weapons, medical diagnostic use and therapeutic use, civil power reactors. The use of x-rays and ankylosing spondylitis has enabled studies to be carried out of the effects of large doses of x-rays; following the use of luminous paints, some people developed and indeed died from bone cancers – others were studied; problems in estimating doses have made these studies difficult and inevitably it is likely that over-estimates rather than under-estimates were used in calculations. The survivors of the atomic bombs dropped on Japan have also been and are being studied. People who have received large therapeutic doses of radiation in recent years can be more easily studied with more accurate information relating to doses received.

BRP3 This is a discussion question with Assessor input.

BRP4 Windscale – During a Wigner energy release from the graphite whilst the reactor was shut down, local overheating rapidly spread somewhat like a chain reaction. The heating was sufficient to ignite the graphite, and the fuel in the reactor was heated to the extent that some isotopes, notably the more volatile iodine, were released. The wind carried iodine to Scandinavia and resulted in much milk in the plume in England being disposed of to waste. The fact that iodine-131 has an 8 day half-life limited the time scale for requiring the disposing of milk.

Three Mile Island – During this incident, generally attributed to human error, radioactive aerosols were released locally to the reactor. The systems in use prevented general release of harmful quantities to the public at large and whilst such an incident was unnecessary, it did prove the effectiveness of design in protecting the public. Nevertheless the public outcry caused a huge decline in the popularity of nuclear power.

Chernobyl – An experiment that was pursued beyond its laid down parameters resulting in an out of control reactor, an explosion and fire releasing a large quantity of radioactive material to the environment. Its local effects were catastrophic to the local environment, to people on the station and in the local town. The town was not evacuated immediately. The wind spread the contamination to many countries, the worst affected being Byelo Russia. There were significant amounts of fallout in the UK due to wind and rain factors.

12 years on, the effects of Chernobyl are still apparent. The damage to the confidence in nuclear power has been enormous in spite of reassurances. The design of the RBMK reactors

was open to much criticism because they are not fail-safe essentially, much modification to design has been carried out to this type of reactor to the extent that such an accident is not now considered a probability.

Tokai Mura Reprocessing Plant – A criticality nuclear excursion occurred in a fuel manufacturing plant when 18 kg of 18% enriched uranium was added to a vessel designed to hold only 2.4 kg. The criticality excursion lasted for 17 hours and resulted in more than 1019 fissions. Three people on the plant received potentially fatal exposures, many others in the plant received serious exposures and some members of the public received exposures of 6-15 mSv. The root causes are seen to be due to poor supervision and training, and poor auditing by the regulator. See IAEA web page.

BRP5 The International Commission on Radiation Radiological Protection, through its various committees, produces reports and recommendations based on the latest knowledge from a wide variety of sources. These reports are issued throughout the world. The National Radiological Protection Board is a body set up by the UK Government. It receives recommendations from the ICRP and advises the government what to include in legislation. It also has a research role and also issues guidance.

BRP6 The ALARA/ALARP principle is the requirement to keep radiation doses as low as reasonably achievable/practicable. The ALARP principle allows a measure of discretion to be observed and takes into account social and economic factors. It does not mean that doses below laid down statutory limits are acceptable. It does mean that whatever the doserate to which people are exposed, steps should be considered, and taken if reasonable to do so, to restrict dose to the lowest reasonably practicable.

BRP7 a) How long will it be accumulated – collection and removal to a 'safe' area before it becomes a radiation or contamination hazard, packaging, sealing, shielding, disposal system. Best method of accumulating at source – quantity limits. How to reduce quantity – not accumulate inactive materials, monitoring (beware ALARP). Limit taking inactive materials into active areas to those that are essential, monitoring systems, etc.

b) Doserates in area? Contamination levels in area, surveys, remote if possible, can these be reduced? Is job necessary, remote cleaning, how long will job take? Can this be reduced by training? Dry runs if necessary to ensure equipment is suitable for the job? Who will do job? Doses? Protection, shielding, tools, etc.

c) Where? Why? What isotopes/materials shielding? Above, below, around, registration records, notices, is it necessary?

d) Similar to b) – more emphasis on contamination control, cleaning – remote if possible – protective clothing, change areas, effect on other people, systems for the removal of waste to prevent build up of contamination/radiation. Operation control from a 'clean' area, dressing and undressing procedures – disposal etc.

BRP8 Justification – no practice involving exposure to radiation should be adopted unless it produces sufficient benefit to either the exposed individuals or to society to offset the detriment it causes.

Optimisation – having justified a practice, it is then necessary to consider what needs to be done in order to reduce the radiation risks to individuals and to the population. The aim is to ensure that the magnitude of doses, the number of people exposed and the possibility of incurring doses are all kept as low as reasonably achievable, economic and social factors being taken into account.

BRP9 See answers to question BRP7. First consider if it is necessary to do it? Can it be done by a different method without radioactive implications eg. Ultrasonics versus radiography. Then all other factors from answer to question BRP7.

BRP10 Need to know that – for stochastic effects – the severity is independent of the dose received – eg leukaemia is contracted, or it is not. However, the probability of producing the effect is proportional to the total dose – no threshold. With deterministic effects, the biological effect increases in severity with the increase in dose. In this case, a threshold dose is evident below which no effect will be observed – Level 2/3 answer. For Level 4, further knowledge required – see ICRP60 3.4.1 and 3.4.2.

BRP11 Guidance on answer – at Level 2, must know that 'justification' demands the consideration and choice between various options to identify those options that can be expected to do more good than harm and from this the preferred option can be selected. When practices involving radiation exposure, or potential exposure are being considered, the radiation detriment must be included explicitly in the choice process. The detriment to be considered is not confined solely to that associated with radiation – it includes other detriments and costs. Justification requires the net benefit to be positive. Once a practice has been justified it is necessary to consider how best to use the resources available to reduce risks to individuals and the general public. The aim being to ensure that doses are kept ALARA economic and social factors being taken into account. Thus the protection can be said to be optimised. At Level 3, more detail is required in relation to the review of existing practices. At Level 4, more detail is required in relation to the ALARA principle and this needs to be applied to individual doses as well as collective doses. ICRP Publication 60 should be used as a reference.

BRP12 This question is similar to BRP6, but more detail must be demanded for Levels 3 and 4. It must give examples of how to achieve low doses – from planning to operational work – and should include dosimetry and its interpretation, as well as the more conventional methods – time/distance/shielding, and combinations of these.

Detection and Measurement of Radiation

DMR1 Photographic film, ionisation, scintillation, other.

DMR2 When ionising particles traverse certain materials, part of their energy may be absorbed and released as visible light. The light can be detected by a photomultiplier where it is converted into an electric charge. This is amplified through the photomultiplier and, at the output, produces a voltage or pulse, the size of which increases with the energy dissipated in the phosphor. By calibrating the counter against a known source it is possible to estimate the efficiency of the counter.

It is important, particularly for alpha particles, that the screen of a probe is very thin (otherwise alpha particles would not penetrate it) that it is light tight (otherwise the photomultiplier would give a false result) and, of course, that the probe has a phosphor coating to absorb the alpha particle and give off the light from this reaction.

DMR3 Ionisation chamber. This works on the principle that a beta particle interacts with matter to produce ion pairs. The ionisation chamber is a gas filled chamber, the inside surfaces of which are conducting. Inside the chamber, and insulated from it, is a central conductor to which is applied an electrical potential. Whenever ionising particles enter the gas inside the chamber, ions are produced and a voltage change occurs at the central electrode. If the rate at which particles enter the chamber is sufficiently high it is possible to measure the current flowing in the central electrode. This current will be equal to the rate at which ionisation is occurring in the gas and hence may be related to the doserate provided the instrument has been suitably calibrated against a source traceable to national standards.

Geiger Muller Tube. Similar, in a way, to the ionisation chamber, the tube has a central wire anode to which is applied a high positive potential. Beta particles entering the counter will produce at least one ion pair. If the potential applied is sufficiently high, the ions will be accelerated and produce other ions, and so on, until the so called avalanche is achieved and the central electrode is surrounded by a sheath of ions, such that avalanche propogation can proceed no further and the electronic circuitry is such that a pulse is recorded as the tube is discharged. Because the whole of the central wire is used in the discharge, the voltage fluctuations are all of the same size irrespective of the amount of primary ionisation, one ion pair liberated is sufficient to cause the discharge. The large voltage changes are easy to observe. Suitable circuitry enables the mean pulse rate to be recorded on a meter.

The instrument needs to be calibrated. Wall thickness is important otherwise lower energy beta particles cannot be measured and, of course, some beta particles have such low energies that it is not possible to obtain a sufficiently thin wall to allow them access. (For 3/4 – might expect more on quenching, dead-time)

DMR4 Thermal neutrons can be measured by using an instrument which employs boron-10 within its make up. The boron-10 absorbs a neutron giving off an alpha particle which will ionise the gas within a chamber. This ionisation can be measured and related to doserate through suitable calibration.

DMR5 Guidance answer – Neutrons are not charged, therefore do not ionise directly, so some material has to be introduced to produce ionisation. Fast neutrons can be detected by causing them to interact with a hydrogenous material to produce protons (knock-on effect) which then produce ionisation. Fast neutron monitors often use a proportional counter with a hydrogenous material incorporated within it. Large amounts of hydrogenous material can also be used to slow the neutrons, which can then be measured as thermal neutrons by boron capture emission of an alpha particle and measurement of the ionisation produced.

DMR6 Certain materials absorb radiations and, if heated, can release the energy as visible light. More radiation – more light measured by the photomultiplier. If calibrated against a known standard source, can give an estimation of dose.

DMR7 Cosmic, terrestrial, radioactive nuclides within the body.

DMR8 Air sampling – possibility of overestimation; environmental contamination/radiation surveys.

DMR9 Improve statistics – random nature of events (enlarge on this for Levels 3 and 4)

DMR10 If an air sample paper is counted immediately upon removal then the daughter products of radon and thoron, which occur naturally, will also be measured. This can give an erroneous result in many cases. The amounts of radon and thoron vary widely from place to place and in relation to weather conditions. Because of the range difference in permissible air concentrations for different isotopes, an innocuous amount of radon/thoron could appear to be a very significant amount of, say, plutonium. Fortunately radon/thoron daughters have a relatively short half life, although for a quick estimate it is important to know what the level of radon/thoron is on a particular day, at a particular time.

DMR11 To avoid losing activity from the paper or cross-contaminating it from another source which could lead to significant errors in estimation.

DMR12 Work arrangement, air flows – no point in sampling up-wind of work if the airflow is away from the sampler. Need to position where it can take a representative sample of what persons are likely to breathe. Positioning at floor level may allow the sampler to collect 'heavy' (large) particles which would not be breathed – hence an over estimation could easily be made.

DMR13 Representative samples difficult to obtain in a working environment – the air sample actually measures what you do not breathe – positioning, particle size, ventilation, etc.

DMR14 Possibility of under or overestimating dose/doserate resulting in incorrect actions being taken. Levels 3 and 4 need to amplify on the implications.

DMR15 Instruments must be tested at least once in every period of 12 months. If a repair has been carried out which may affect the calibration then a calibration should be carried out before the instrument is put back into use. If at any time the calibration is thought to be suspect it should be checked. Function test before use.

DMR16 Personal whole body dosemeter, film, electronic, thermoluminiscent dosemeters may also be useful to check extremities or different parts of the body – because of the difference in doserates from one place to another. A personal air sample may be appropriate, depending on degree of personal protection. Dosemeters, giving warnings at preset doserates and at preset accumulated dose levels, should also be worn.

DMR17 Poor flow rates and difficulty in preventing cross-contamination, as well as difficulty in getting a representative sample, make dose estimation difficult.

DMR18 Urine sampling, faeces sampling – to get a measure of excretion rates which, when related to the isotope(s), will assist dose estimation. Whole body monitoring might also be appropriate depending on the isotopes involved. Thyroid monitoring; wound monitoring.

DMR19 Check the instrument against known sources traceable to national standards. Check the instrument in at least two positions on each range – or if a log scale, at several appropriate points. Calibrate in an appropriate area – remotely exposing sources at the measured distances required. The area should be one in which back scattering is minimal. A greater depth of knowledge would be expected from Level 3/4.

DMR20 Whole body monitoring, blood monitoring, faeces monitoring, urine monitoring – need for follow up monitoring to measure changes in position – excretion rates, levels, knowledge of isotope/material chemical and physical form, etc.

DMR21 The 'dead time' of a counter is the period that elapses between its ability to count pulses after counting one pulse – the counter needs time to recover. May be aided by quenching agents. However, at very high count rates, the 'dead time', although very small, may be significant – ie dead time x count rate will give the time the counter is not counting and thus a true count rate is not registered.

DMR22 a) Geiger tube; b) scintillation detector. Geiger will not have sufficient stopping power for gamma rays. Scintillation detector casing may prevent penetration of low energy betas.

DMR23 Thin window, thin crystal scintillation detector.

DMR24 Wipe testing using alcohol impregnated swab. Swab wiped over known area ($100cm^2$) and counted in liquid scintillation counter. Comparison with standard gives activity on swab. Assume 10% efficiency for transfer of tritium from bench to swab. Surface contamination can be determined by dividing by area wiped.

DMR25 Wipe testing using alcohol impregnated swab. Swab wiped over known area ($100cm^2$) and monitored with sensitive contamination monitor. If activity detected, swab counted in gamma counter. Assume 10% efficiency for transfer of tritium from bench to swab. Surface contamination can be determined by dividing by area wiped.

DMR26 Whole body monitor worn at waist level. Monitor will use either film or TL material as the detector. Film more effective in determining radiation source. TL dosemeter cheaper and more efficient.

DMR27 Potential for contamination of badge.

DMR28 In addition to a whole body monitor worn below the lead apron, a finger stall monitor should be worn routinely and, if lead glasses not worn, consideration should be given to wearing a 'head band' with TL monitor to monitor the eye dose.

Legislation

L1 Regulations **must** be complied with. An approved Code of Practice tells how best to do something and how best to comply with a regulation. Codes of Practice do not have the force of law but if an infringement of a code occurs then this can be used in evidence against an individual or body corporate. Regulations Guidance provides advice to those with responsibilities under the IRR99.

L2 The Ionising Radiations Regulations 1999 require that Radiation Employers shall consult with suitable Radiation Protection Advisors (RPAs) for the purpose of advising them on the observance of the IRR99. The Radiation Employer appoints in writing one or more suitable RPAs defining their scope. An RPA is an individual who meets the HSE Criteria of Competence by achieving a National or Scottish Vocational Qualification (N/SVQ) Level 4 in Occupational

Health and Safety with the appropriate Radiological Protection Units or having a Certificate awarded by an HSE recognised Assessing Body. An organisation may be recognised by the HSE as an RPA Body provided it meets the HSE Criteria for such recognition. Note that transitionally until December 2004 an RPA, or RPA Body, is someone or organisation who has ever held an appointment as an RPA under the IRR85.

Qualified Persons are persons given the tasks of carrying out or supervising tests on radiation monitoring equipment and authorising the records of such tests as specified in IRR99 Regulation 19.

A Radiation Employer is required to appoint one or more Radiation Protection Supervisors for the purpose of securing compliance with the Regulations in respect of work carried out in any area subject to Local Rules for work in Controlled or Supervised Areas. Their area of work needs to be defined and they must be trained so that they understand the requirements of legislation and local rules insofar as they affect their area of work. They also need to understand the reasons for the precautions that need to be taken in their area of work and the precautions that need to be taken in their area of work and should command the respect of those they supervise.

L3 No – This may only be done by a Service Approved by the Health and Safety Executive. Levels 3 and 4 need to give explicit reasons – reference to legislation, etc.

L4 This dose exceeds 15mSv therefore there is a need to investigate to ensure that work is being carried out in accordance with the ALARP principle. The 15mSv dose is a useful trigger in this regard – it may be, of course, that the dose is false which may also be determined by investigation. There may also be local rules that require an investigation at a lower limit.

L5 Regulation 27 requires that any article containing or embodying a radioactive source should, as far as reasonably practicable, be leakproof and requires only that 'suitable tests are carried out at suitable intervals.' Fuller details are contained in the ACOP which recommends a minimum of every two years.

L6 The driver needs to know – where he is going, the route to follow, what he is carrying, who to give the consignment to, what to do if he has a problem, where he may or may not leave the vehicle, what notices he must display, who to contact – telephone numbers at various parts of the route, if necessary – not exhaustive, depends to some extent on the type of package. Must follow the requirements of local rules and of the transport legislation

L7 It is important that candidates fully understand the use and validity of Local Rules, Special Procedures and the need to keep conditions under review. See Regulation 18(2)(c).

L8 For answer, see Regulation 20(1)– IRR99.

L9 For answer, see Regulation 21 – IRR99.

L10 For answer, see Regulation 23 – IRR99.

L11 For answer, see Regulation 24 – IRR99.

L12 For answer, see Regulation 28 – IRR99.

L13 For answer, see Regulation 19 – IRR99.

L14 For answer, see Regulation 25 – IRR99.

L15 For answers a) to d) , see Regulation 11, Schedule 4, – IRR99. For answer e) see Regulation 8 (5).

L16 For answer, see Regulation 16 and ACOP.

L17 For answer, see Section 6/7 of Radioactive Substances Act 1993

L18 For answer, see Section 8 of Radioactive Substances Act 1993

L19 For answer, see Sections 21 and 22 of Radioactive Substances Act 1993. For Levels 2 and 3, the answer need only state that an Enforcement notice allows work to continue, provided steps are taken to remedy the matters detailed in the notice, and that the notice will also state the period in which the matters will be put right. A prohibition notice will also require steps to be taken to remedy any shortcomings within a stated time period but, until the notice is withdrawn, registration or authorisation will cease to have effect to the extent specified in the notice. Level 4 will be expected to give more of the detail in Section 21 and 22 of the Act.

L20 For answer, see Sections 13 and 14 of Radioactive Substances Act 1993. A Level 3 answer will be fairly simple. Level 4 requires more detail.

L21 The Health and Safety at Work etc. Act 1974 applies to all forms and places of work and that includes work with ionising radiation. For levels 2 and 3 the answer need only state that an Improvement Notice allows work to continue provided steps are taken to comply with the requirements of the notice which will state the period in which these must be completed. A Prohibition Notice requires the immediate cessation of the work while the steps to comply with the requirements of the notice are carried out. Level 4 will be expected to give more of the detail in the Act.

Control of exposure.

CE1 External radiation hazards are those from sources outside the body such that there is no possibility of these entering into the body as particulate contamination. In general such sources can be shut off, removed or a person can leave an area in which they arise.

Internal radiation hazards occur where it is possible for radioactive materials to be taken into the body from contamination on articles or from airborne contamination. This may be by inhalation, ingestion, through the skin or through a break in the skin. Once inside the body such contamination will continue to irradiate the person until it has been excreted, decayed away or otherwise removed.

CE2 Important to ensure that candidates appreciate that, often, any one of these is not sufficient on its own to ensure that doses are ALARP. It is no good to shield something to a very low doserate which makes working on it so difficult that the time taken to do the job is drastically increased. Combinations of shielding and tools which provide some distance, but still allow relatively quick manipulation must be considered in order to assess how to achieve the lowest dose within the ALARP principle – dummy runs are often very important in order to assess time.

CE3 912.5 μSv/h at 2 metres.

CE4 The employer should make an assessment of the work being, or to be, carried out in any particular area. The area should be designated as ‘controlled’ if, after consulting the RPA, it appears necessary to set up special procedures for persons in the area, whether for routine procedures or for accidents, in order to prevent significant exposures and in any event if persons are likely to receive more than 6mSv per year. Any area where the employer finds it necessary to keep conditions under review to check if the area should be designated as controlled, or if the area is such that persons may receive more than 1mSv, should be designated as ‘supervised’.

However, the Approved Code of Practice provides guidance on the designation of areas and indicates that areas should be designated as controlled if the external doserate averaged over the working day exceeds 7.5 microsieverts per hour; in the special case of site radiography the condition is that the doserate should be averaged over one minute. An area should also be designated as controlled if there is a significant risk of spreading radioactive contamination outside the working area.

Controlled areas should be physically demarcated or, where that is not reasonably practicable, suitably delineated. Signs should be displayed in controlled and supervised areas to indicate that the area is controlled and providing information about the nature and risks of the radiation sources.

Persons entering a controlled area should either be classified or be entering in accordance with 'written arrangements' designed to ensure that doses will not exceed, in case of persons over 18, levels which would otherwise require the persons to be classified (ie 6mSv per year effective dose). In the case of other persons the relevant dose limit is applicable.

CE5 Ventilation provides a way of controlling air, which may be contaminated eg from fume cupboards or other areas and where breathing apparatus of one kind or another may be a requirement, in such a way that persons are very unlikely to be exposed to airborne hazards: the air entering the area will be clean air. This air will be changed frequently, the frequency depending on the likely hazard – more changes per hour in a more hazardous area, thus workers can be protected. By filtering and monitoring air extracted, the general public will not be exposed to any hazard from the effluent gases. It is important that routine monitoring of ventilation plant ensures that flow rates are properly maintained and filtering systems are effective – maintenance of fans and of other equipment. Importance of proving filter installation integrity.

CE6 If the area in which one works is kept clean and clear of unnecessary hazards, it is a fact that accidents/incidents are much less likely to occur. It is also easier to maintain, monitor and to clean in the event of a spill.

CE7 Routine monitoring ensures that the situation assessed has not changed, that doing work or removing something, for instance, has not generated an unforeseen hazard. As with any routine monitoring it is confirmation that changes have not occurred or, if they have, they are discovered very quickly.

CE8 Answer guidance – Shielding, interlocks (doors and x-ray sets). Alarms, notices, shielded refuge, able to shut off inside, able to open from inside, permits. Requirements for an alarm button inside area and warning alarms/lights for when sources are ready to be exposed and are exposed, or when an x-ray beam is about to exposed and is exposed.

CE9 Protective clothing required – ideally, full air line suit with lightweight disposable oversuit to prevent contamination of main suit and possible exposures during cleaning; disposable over hood for similar reasons; over gloves; dosimetry – personal dosemeter film/electronic, other, backed up by alarm dosemeters (doserate and accumulated dose) extremity monitors, thermoluminescence or similar. Do not forget that the beta contribution may be very significant – need to measure the beta:gamma ratio.

CE10 Ensure that the required warning notices are positioned to warn public. Ensure warning audible signals/light signals are operating, check source is correct one for job, has been leak tested as required. Ensure area is clear before exposing the source. Sound warning signal before exposing source, and while the source is exposed – different warning signal – operate lights if not automatic – expose source – radiation check of area, return source to store after appropriate exposure – radiation check to ensure source has returned to store. Similar, if mobile x-ray is used – ensure switched off by monitoring. Level 2 requires basic knowledge only; Level 3 needs to know reasons; Level 4 should know all the relevant doserates and should know about permit requirements and when local rules may be adequate with proper supervision.

CE11 This is typical of a question suitable for discussion between the candidate and mentor/assessor which will help the assessor to judge how a candidate would handle contingencies for which performance evidence is not available. Expected answers would show how the candidate would: verify the report, deal with the person – possibly by handing over to someone else, report in accordance with local rules, ensure that other staff in the area were informed/monitored/removed if necessary, question person as to where he/she had been, what he/she had been doing, who else was with him/her, monitoring, barriering area, providing warning notices etc. All aimed at ensuring that people were not subjected to unnecessary hazards, that the extent of the incident was limited and not getting worse. The question could include details of levels of contamination from very little to gross, which would ensure that the correct level of response would be taken according to the NVQ Level 2/ 3/ 4.

CE12 Filter checks, box integrity check, routine contamination/radiation monitoring as appropriate, frequent radiation/contamination check of gloves, smear/swab monitoring of gloves, ensure maintenance programme properly carried out in accordance with local rules.

CE13 Answer similar to CE5

CE14 a) taken up by marine life, – fish caught and eaten.

b) deposited on shore/beach, dries out and becomes airborne, breathed in or picked up on shoes/hands, taken home, cross contamination of food eaten.

c) absorbed by plants which may be part of food chain.

CE15 Limit materials in use, ensure integrity of filter systems and check regularly, monitor discharges after filters, records, ensure any specified limits for contents of ventilated areas are complied with. Don't forget that an absolute filter which has been certified for its integrity is useless if the housing it is in leaks, therefore the installation needs to be checked after any filter change.

CE16 Radioactive arisings can be minimised by: using the minimum amount of a radioactive substance required to fulfill a task, ensuring that no unnecessary inactive material is taken into a controlled area – packaging etc. Monitor materials out of a controlled area – proper preparation of work and planning of work, use of minimum amounts of cleaning materials but adequate for job – don't skimp but don't be wasteful. Systems for re-using materials – keeping close scrutiny of working practices and identifying areas where savings can be made – listen to workers ideas and get them involved, explain why.

CE17 This question would better form a project preferably linked to work but could still be used as a discussion question with the asessor.

CE18 a) When operating, routine radiation surveys for gamma radiation and neutrons should be carried out. Set point monitoring should be included but general monitoring is also necessary. This is to ensure that nothing is changing and that nothing unexpected has occurred. Contamination surveys both for surface and airborne contamination should also be carried out for similar reasons.

b) When a reactor is shut down for maintenance, much more routine monitoring is required both for radiation and contamination, particularly in areas where the reactor integrity has been breached. Blower maintenance, boiler entry etc – the likelihood for spread of contamination is enhanced.

CE19 a) When a reactor is operating, hazards are generally those associated with radiation from circuitry, gas, water, etc and possibly weaknesses in shielding. Radiation from sampling systems are also possible – B.C.D. systems etc.

b) When shut down, the main hazards are usually associated with contamination hazards, as well as radiation hazards due to maintenance work in normally sealed areas.

CE20 Inhalation – protect by keeping radioactive material in closed ventilated containment, or if not possible, protect people with air fed apparatus or in some circumstances respirators.

Ingestion – keep radioactive material in closed containment, or if not possible, protect by using protective clothing and local rules, no eating, drinking, smoking, sucking fingers, touching exposed parts of the body etc.

Absorption – through skin, or breaks in the skin: protective clothing, limit sharp objects, training, care with chemicals that may penetrate skin.

CE21 Warn people, monitor, notify superiors, notify dispatching authority, question route, monitor vehicle, depending on size of problem may need to notify HSE. Investigate whether, from consignment or other contamination, check and monitor people who have been involved in handling the consignment, check whether likely to have spread from vehicle, other actions depending on what is found.

CE22 Notify people in the area, notify supervisor, monitor people, move people to a clean area – the nearest, monitor them, erect barriers, run air samplers in area. When people have been dealt with and area isolated, consider plan for cleaning up the area and finding the cause. Important to check whether the problem is worsening or static, need to check outlets to other areas, to atmosphere etc. Put into effect contingency plan, if warranted.

CE23 Similar actions to CE22. Need to check source store and ascertain movements of sources in use, so that monitoring can be carried out. Need to establish whether a source is leaking or if contamination is from elsewhere.

CE24 Time /distance /shielding, a combination of these, identification of the area of lowest doserate to use in waiting periods, etc. See also answer to CE2.

CE25 Total protection of air supply and more comfortable to work in, are advantages. Disadvantages are – limited distance in which one can move, need for a special compressor giving clean air, time taken to dress/undress, etc.

CE26 In a non respirable atmosphere. In very high airborne contamination levels. In a respirable atmosphere contaminated by gases which are poisonous to health and which are not excluded by any filtering canister.

CE27 Large insoluble particles will be trapped before entering the lung and removed to be swallowed. Small insoluble particles may reach the lungs and remain there. Large soluble particles will be swallowed and absorbed into the body, where they may be preferentially absorbed by particular organs – whereas, if insoluble, they will be excreted. Small soluble particles may reach the lungs but will be absorbed into the body and may be preferentially absorbed by a particular organ. Whether a substance is absorbed by a particular organ will depend on the body's metabolism. In essence, the same amounts of radioactive materials in different chemical or physical forms, may have a very marked difference in the dose absorbed by the body.

CE28 The main point of this question is to check that the candidate appreciates that it is not always necessary to smear test the source. In the case given, it is sufficient to remove the tube and check the inside for contamination – ALARP.

CE29 a) In a high background area

b) Where it is not possible to get a probe to give a direct reading eg inside a small pipe.

c) When it is necessary to assess loose contamination levels.

CE30 The answer to this question will be site specific

CE31 The answer to this question will be site specific

CE32 A distance of 1.5m from the tube head or patient avoiding the direct beam.

CE33 Supervised areas; local rules; RPS; hard, smooth, impermeable flooring and bench surfaces coved at the edges, spill kit, designated sink and solid waste disposal, storage fridge/cupboard for sources, warning signs.

CE34 Designated sink.

CE35 Controlled area; local rules; RPS; warning signs, contingency plans, interlock systems.

CE36 Wipe testing using alcohol impregnated swab and monitored with sensitive contamination monitor. If activity detected which is >3 times SD of background leakage reported to source supplier, Selectron withdrawn from use.

CE37 Answer requires knowledge of X-ray source (kV, mA, filtration); FFD; detector (film, film screen systems, CR and DR devices); processing; safety issues – DAP meter, scatter reduction.

Additional Guidance for Assessors on Practical Work

Where the amount of practical work associated with basic knowledge may not be adequately covered in the course of normal work, assessors may be able to suggest ways in which candidates may be given practical tasks/projects as an extension to their normal work. The following is a list of practical exercises which assessors may like to consider:

1. Determination of the efficiency of counting systems. Routine checks to ensure that equipment is functioning correctly.
2. Simple repairs to instruments, batteries, foils, replacement of tubes.
3. Determination of a plateau, operating voltages.
4. Statistics associated with counting – random nature of radioactive disintegration procedures.
5. Preparation of sources for counting/liquid counting.
6. Radioactive decay – can use natural activity collected by air sample.
7. Monitoring techniques – alpha/beta/gamma/beams/beta-gamma in presence of gamma background.
8. Light sensitivity of probes
9. Smear/swab monitoring, differentiating between loose and fixed contamination, determination of activity removed by smear/swabs from surfaces.
10. Air sample, natural activity, techniques for handling papers etc.
11. Instrument familiarisation.
12. Relation between a contact dose and true surface dose. Inverse square law.
13. Calculation of working times in mixed radiation fields.
14. Simple instrument calibration.
15. Leak tests of sealed sources.
16. Shielding/absorption experiments.
17. Monitoring procedures.
18. Barrier procedures.
19. Dressing/undressing procedures.
20. Washing procedures.
21. Change room procedures/rules.
22. Monitoring cuts/wounds/skin.
23. Drills for small incidents measurements required to assess scale of incident/actions to be taken.
24. Barrier drill for large incidents.
25. Operational control of potentially hazardous work. Planning inside/outside affected area, remedial work etc – local rules/arrangements.
26. Choice and use of protective clothing, respiratory protection, checks of equipment, pre-use checks, fire drills.
27. Incident drills and exercises.
28. Construction of shielding.
29. Spectrometry.
30. Low level monitoring surveys/environmental monitoring.

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