THE NUCLEUS

1. Indicate the number of neutrons in each of the following nuclei.
a) ^{10}Be **b)** ^{100}Mo **c)** ^{75}As **d)** ^{197}Au

2. Indicate the number of neutrons in each of the following nuclei.
a) ^{192}Hg **b)** ^{115}Sn **c)** ^{34}S **d)** ^{85}Rb

3. Write the symbol, including atomic number and mass, for each of the following isotopes.
a) Z = 26, A = 56 **b)** A = 74, N_n = 40 **c)** Z = 54, N_n = 78

4. Write the symbol, including atomic number and mass, for each of the following isotopes.
a) Z = 46, N_n = 64 **b)** A = 110, Z = 48 **c)** A = 212, N_n = 129

5. There are three naturally occurring isotopes of silicon. Use the data below to determine the atomic mass of silicon.

	Mass (amu)	Abundance
^{28}Si	27.97693	92.21%
^{29}Si	28.97649	4.70%
^{30}Si	29.97376	3.09%

6. There are two naturally occurring isotopes of lithium: ^{6}Li and ^{7}Li, with atomic masses of 6.01512 and 7.01600, respectively. If the atomic mass of lithium is 6.939, what is the natural abundance of ^{6}Li?

7. The natural abundance of deuterium is 0.015%. How many deuterium nuclei are present in 100. mL of water?

NUCLEAR STABILITY

8. What is meant by the term 'band of stability'?

9. Determine the mass defects (in kg·mol^{-1}) for the following nuclei.
a) ^{79}Br (Mass = 78.9183 amu)
b) ^{99}Ru (Mass = 98.9061 amu)

10. Determine the mass defects (in kg·mol^{-1}) for the following nuclei.
a) ^{142}Ce (Mass = 141.9090 amu)
b) ^{40}Ca (Mass = 39.96259 amu)

11. What are the binding energies and binding energies per nucleon for each of the nuclei in Exercise 9?

12. What are the binding energies and binding energies per nucleon for each of the nuclei in Exercise 10?

13. Which nucleus in Exercise 11 is thermodynamically more stable?

14. Which nucleus in Exercise 12 is thermodynamically more stable?

NUCLEAR REACTIONS AND RADIOACTIVITY

15. Predict the mode of decay for each of the following:
a) ^{233}U **b)** ^{197}Pb **c)** ^{231}Ac **d)** ^{225}Th

16. Predict the mode of decay for each of the following:
a) ^{110}Rh **b)** ^{98}Pd **c)** ^{6}He **d)** ^{25}Al

17. Identify X in each of the following nuclear reactions:
a) $^{144}\text{Nd} \rightarrow {}^{140}\text{Ce} + \text{X}$
b) $^{238}\text{U} + \text{n} \rightarrow 3\text{n} + {}^{81}\text{Ge} + \text{X}$
c) $^{16}\text{O} + \alpha \rightarrow \text{X}$

18. Identify X in each of the following nuclear reactions.
a) $^{69}\text{Ga} + \text{n} \rightarrow \text{X}$
b) $^{235}\text{U} + \text{n} \rightarrow 2\text{n} + {}^{100}\text{Mo} + \text{X}$
c) $^{35}\text{Cl} + \text{p} \rightarrow \alpha + \text{X}$

19. Write complete nuclear reactions for the following:
- **a)** Potassium-40 undergoes beta decay.
- **b)** Chlorine-34 emits a positron.
- **c)** Arsenic-73 undergoes electron capture.
- **d)** Bismuth-214 decays to thallium-210.

20. Write complete nuclear reactions for the following.
- **a)** Thorium-229 undergoes alpha decay.
- **b)** Gold-198 emits a beta particle.
- **c)** Antimony-118 emits a positron.
- **d)** Cadmium-115 decays to indium-115.

21. Radon-222 undergoes the following decay sequence to a stable nucleus: α, α, β, β, α, β, β, α. What is the identity of the resulting nucleus?

22. Uranium-238 undergoes the following decay sequence: α, β, β, α, α, α, α, α, β, β, α, β. What is the identity of the last nucleus?

KINETICS OF RADIOACTIVITY

23. ^{239}Pu is a very toxic material used in nuclear weapons that has a half-life of 2.44×10^4 years. How long will a sample of Pu have to be stored before only 1% of the original sample remains?

24. ^{131}I is a β-emitter that is used to treat thyroid disorders. If its half-life is 8.070 days, how many days are required to rid the body of 95% of any ingested ^{131}I?

25. A 12.30-mg sample of ^{47}Ca is found to contain 3.24 mg of ^{47}Sc after 2.00 days, what is the half-life of ^{47}Ca in days? What type of decay does ^{47}Ca undergo?

26. A 4.56-mg sample of ^{228}Th, an α emitter, contains 2.58 mg of ^{228}Th after 575 days. What is the half-life of ^{228}Th in years?

27. The Shroud of Turin is a long linen cloth that bears an image of a bearded, longhaired man, with numerous lacerations over his body. Tradition, dating back to the fourteenth century, has it that the fabric is the burial shroud of Jesus Christ. In 1988, its age was determined by carbon dating. If a fiber of the shroud had a ^{14}C disintegration rate of 14.0 $d \cdot min^{-1} \cdot g^{-1}$, how old was the cloth. What conclusion can be drawn about the authenticity of the claim that it is the burial cloth of Jesus Christ? (The rate of decay of living organisms is 15.3 $d \cdot min^{-1} \cdot g^{-1}$, and the half-life of ^{14}C is 5730 years.)

28. The wood on an Egyptian coffin had a ^{14}C disintegration rate of 11.7 $d \cdot min^{-1} \cdot g^{-1}$, how old is the coffin? (The rate of decay of living organisms is 15.3 $d \cdot min^{-1} \cdot g^{-1}$, and the half-life of ^{14}C is 5730 years.)

29. How old is a rock sample from a meteor if it contains 73.2 mg of ^{238}U and 20.2 mg of ^{206}Pb? Assume that all of the ^{206}Pb was formed from ^{238}U. The half-life of the $^{238}U \rightarrow {}^{206}Pb$ process is 4.5×10^9 years.

30. Geological times can also be estimated by Argon dating. ^{40}K undergoes electron capture to ^{40}Ar with a half-life of 1.28×10^9 years. Estimate the age of a moon rock sample if its $^{40}Ar/^{40}K$ mass ratio is 10.4.

NUCLEAR RADIATION

31. List beta particles, gamma rays and alpha particles in order of increasing penetrating power.

32. Why are houses checked for radon? How does radon get into a home?

NUCLEAR FISSION AND NUCLEAR FUSION

Use the following atomic masses and those in Table 11.1 for Exercises 33 and 34.

^{4}He	4.0026	^{13}C	13.0034	^{31}P	30.9737
^{16}O	15.9949	^{24}Mg	23.9850	^{226}Ra	226.0254
^{68}Zn	67.9248	^{72}Ge	71.9221	^{238}U	238.0508
^{230}Th	230.0331	^{234}Th	234.0436		
^{239}Pu	239.0522	^{242}Cm	242.0588		

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33. Determine the mass defect in kilograms of each of the following reactions.

a) $2\,^{12}C \rightarrow {}^{24}Mg$ **b)** $^{238}U \rightarrow {}^{234}Th + \alpha$

c) $\beta^{+} + \beta^{-} \rightarrow \gamma$ **d)** $^{239}Pu + {}^{4}He \rightarrow {}^{242}Cm + n$

34. Determine the mass defect in kilograms of each of the following reactions.

a) $^{230}Th \rightarrow {}^{226}Ra + \alpha$ **b)** $2\,^{16}O \rightarrow {}^{31}P + {}^{1}H$

c) $^{13}C + {}^{4}He \rightarrow {}^{16}O + n$ **d)** $^{68}Zn + {}^{4}He \rightarrow {}^{72}Ge$

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35. What is the energy change of each reaction listed in Exercise 33?

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37. Classify each reaction in Exercise 33 as fission, fusion, decay or annihilation. If it is a decay, indicate what kind.

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39. What is a chain reaction? How is the chain reaction in a nuclear power plant controlled?

40. Why is controlled fusion so difficult to achieve? Describe the two methods that are being used to produce controlled fusion