UNIT 6 - RADIOACTIVITY AND NUCLEAR CHEMISTRY

6.4 HONORS CLASS WORKSHEET – NUCLEAR ENERGY

1. Binding Energy and Mass Defect

Consider the following nuclear reaction: $^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$ mass of $^{2}_{1}\mathrm{H}$ = 2.014 amu, mass of $^{3}_{1}\mathrm{H}$ = 3.016 amu, mass of $^{4}_{2}\mathrm{He}$ = 4.003 amu, mass of $^{1}_{0}\mathrm{n}$ = 1.009 amu Show your working in all calculations:		
(a)	Calculate the mass defect for this reaction (in amu)	Mass of products – mass of reactants (in amu) 5.030 – 5.012 = 0.018 amu
(b)	Calculate the mass defect for this reaction (in kg) (1 amu = 1.66 x 10^{-27} kg)	Multiply (a) by 1.66 x 10^{-27} 3.0 X 10^{-29} kg
(c)	Calculate the energy released during this reaction (per He atom) (c = 3 x 10^{8} m/s)	Multiply (b) by c^2 2.7 x 10^{-12} J
(d)	Calculate the energy released during this reaction (per mole of He atoms) (L = 6.02 x 10^{23} mol^{-1})	Multiply (c) by L 1.6 x 10^{12} J/mol or 1.6 x 10 kJ/mol

2. Nuclear fission

An example of a nuclear fission reaction is $^{235}_{92}\mathrm{U} \rightarrow {}^{141}_{56}\mathrm{Ba} + {}^{92}_{36}\mathrm{Kr} + 2{}^{1}_{0}\mathrm{n}$		
(a)	Write nuclear equations for the following fission reactions:	
	(i)	The fission of Uranium-235 to produce caesium-144 and rubidium-90
		$^{235}_{92}\mathrm{U} \rightarrow {}^{144}_{55}Cs + {}^{90}_{37}\mathrm{Rb} + {}^{1}_{0}\mathrm{n}$
	(ii)	The fission of plutonium-239 to produce xenon-134 and zirconium-103
		$^{239}_{94}\mathrm{Pu} \rightarrow {}^{134}_{54}\mathrm{Xe} + {}^{103}_{40}\mathrm{Zr} + 2{}^{1}_{0}\mathrm{n}$
(b)	Explain why nuclear fission can result in a "chain reaction".	
	The reaction produces neutrons which collide with more nuclei causing more fission	
(c)	Explain the role of boron rods in a nuclear reactor.	
	They control the reaction rate by absorbing surplus neutrons	
(d)	Explain the main environmental problem associated with nuclear fission reactions.	
	The daughter nuclei are themselves radioactive and hence difficult to safely dispose of	

3. Nuclear fusion

<table>
<tr><td colspan="3">An example of a nuclear fusion reaction is $^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$</td></tr>
<tr><td>(a)</td><td colspan="2">Where does the above reaction take place and why is it important?</td></tr>
<tr><td></td><td colspan="2">In the sun; it makes the sun shine and is the source of all our energy</td></tr>
<tr><td>(b)</td><td colspan="2">Write nuclear equations for the following fusion reactions:
(copy the above equation and change the symbols)</td></tr>
<tr><td></td><td>(i)</td><td>The fusion of two hydrogen-2 nuclei to produce helium-3 and one other particle</td></tr>
<tr><td></td><td></td><td>$^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$</td></tr>
<tr><td></td><td>(ii)</td><td>The fusion of hydrogen-1 and carbon-12 into a single particle</td></tr>
<tr><td></td><td></td><td>$^{1}_{1}\mathrm{H} + {}^{12}_{6}\mathrm{C} \rightarrow {}^{13}_{7}\mathrm{N}$</td></tr>
<tr><td>(c)</td><td colspan="2">Give two reasons why nuclear fusion is, in principle at least, a better way to generate nuclear power than nuclear fission</td></tr>
<tr><td></td><td colspan="2">- products are not reactive so no disposal issues
- you get much more energy per atom
- raw materials are much cheaper</td></tr>
<tr><td>(d)</td><td colspan="2">Give two reasons why there are currently no nuclear fusion power stations on earth.</td></tr>
<tr><td></td><td colspan="2">- Nuclei repel so high temperatures needed to get reaction started
- So much energy is released that the reaction is very difficult to control</td></tr>
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