Chemistry:
Transition from GCSE to AS level

Part 10 - Atom economy

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Percentage atom economy

- It is sometimes useful to express the theoretical maximum mass of a particular product as a percentage of the total mass of reactants
- This is called the percentage atom economy.
- If percentage atom economy is high there is very little waste in a reaction.

$$\text{Percentage atom economy} = \frac{\text{mass of desired product}}{\text{total mass of reactants}} \times 100$$

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Calculation of percentage atom economy can be done using relative molar masses (Mr) and a balanced equation

$$\%\ \text{atom economy} = \frac{\text{Mr of desired product}}{\text{sum of the Mr values of all reactants}} \times 100$$

Calculate the percentage atom economy for the production of magnesium hydroxide by the reaction of magnesium chloride with sodium hydroxide:

$$MgCl_2 + 2NaOH \rightarrow Mg(OH)_2 + 2NaCl$$

Calculate the percentage atom economy for the production of magnesium hydroxide by the reaction of magnesium chloride with sodium hydroxide:

$MgCl_2$	+	$2NaOH$	$\rightarrow$	$Mg(OH)_2$	+	$2NaCl$
95.3		40.0		58.3		58.5

Calculate the percentage atom economy for the production of magnesium hydroxide by the reaction of magnesium chloride with sodium hydroxide:

$$MgCl_2 + 2NaOH \rightarrow Mg(OH)_2 + 2NaCl$$

95.3 40.0 58.3 58.5

Percentage atom economy

$$= \frac{58.3}{95.3 + 2(40.0)} \times 100$$

$$= \frac{58.3}{175.3} \times 100 = 33.3\%$$

This reaction is inefficient as a large amount of the waste product sodium chloride is formed.

Finally - there are two ways to increase the atom economy.

1. Find an alternative route to the desired product

2. Find a use for the other product(s) - this is likely to increase the atom economy to 100% !

The Periodic Table of the Elements

1	2											3	4	5	6	7	0
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*	*(16)*	*(17)*	*(18)*
							1.0 **H** hydrogen 1										4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12											27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	96.0 **Mo** molybdenum 42	[97] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La** * lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac** † actinium 89	[267] **Rf** rutherfordium 104	[270] **Db** dubnium 105	[269] **Sg** seaborgium 106	[270] **Bh** bohrium 107	[270] **Hs** hassium 108	[278] **Mt** meitnerium 109	[281] **Ds** darmstadtium 110	[281] **Rg** roentgenium 111	[285] **Cn** copernicium 112	[286] **Nh** nihonium 113	[289] **Fl** flerovium 114	[289] **Mc** moscovium 115	[293] **Lv** livermorium 116	[294] **Ts** tennessine 117	[294] **Og** oganesson 118

Key

relative atomic mass
symbol
name
atomic (proton) number

140.1 **Ce** cerium 58	140.9 **Pr** praseodymium 59	144.2 **Nd** neodymium 60	[145] **Pm** promethium 61	150.4 **Sm** samarium 62	152.0 **Eu** europium 63	157.3 **Gd** gadolinium 64	158.9 **Tb** terbium 65	162.5 **Dy** dysprosium 66	164.9 **Ho** holmium 67	167.3 **Er** erbium 68	168.9 **Tm** thulium 69	173.0 **Yb** ytterbium 70	175.0 **Lu** lutetium 71
232.0 **Th** thorium 90	231.0 **Pa** protactinium 91	238.0 **U** uranium 92	[237] **Np** neptunium 93	[244] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[247] **Bk** berkelium 97	[251] **Cf** californium 98	[252] **Es** einsteinium 99	[257] **Fm** fermium 100	[258] **Md** mendelevium 101	[259] **No** nobelium 102	[262] **Lr** lawrencium 103

* **58 – 71** Lanthanides

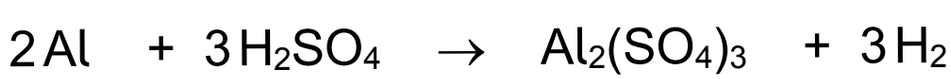
† **90 – 103** Actinides

Use this for the task on the next page

1. Calculate the percentage atom economy for the production of potassium sulfate by the reaction of potassium hydrogencarbonate with sulfuric acid:

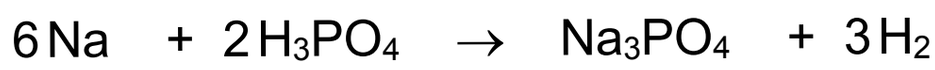
$$2\,KHCO_3 + H_2SO_4 \rightarrow K_2SO_4 + 2\,H_2O + 2\,CO_2$$

2. Calculate the percentage atom economy for the production of aluminium sulfate by the reaction of aluminium with sulfuric acid:



$$2\,Al + 3\,H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3\,H_2$$

3. Calculate the percentage atom economy for the production of sodium phosphate by the reaction of sodium with phosphoric acid:



$$6\,Na + 2\,H_3PO_4 \rightarrow Na_3PO_4 + 3\,H_2$$

Pause this presentation while you complete the exercise on the previous page.

When complete move to the next page where you can check your answers.

1. Calculate the percentage atom economy for the production of potassium sulfate by the reaction of potassium hydrogencarbonate with sulfuric acid:

$$2\ KHCO_3 + H_2SO_4 \rightarrow K_2SO_4 + 2\ H_2O + 2\ CO_2$$

$$\frac{174.3}{2(100.1)+98.1} \times 100 = 58.4\%$$

2. Calculate the percentage atom economy for the production of aluminium sulfate by the reaction of aluminium with sulfuric acid:

$$2\ Al + 3\ H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3\ H_2$$

$$\frac{342.2}{(2\times 27)+3(98.1)} \times 100 = 98.2\%$$

3. Calculate the percentage atom economy for the production of sodium phosphate by the reaction of sodium with phosphoric acid:

$$6\ Na + 2\ H_3PO_4 \rightarrow 2\ Na_3PO_4 + 3\ H_2$$

$$\frac{2(163.9)}{6(23)+2(98)} \times 100 = 98.1\%$$

Having checked your work you will have either:

1. Completed the task correctly - well done :)

2. Made some mistakes - which you now understand (having seen the correct answer) - that's OK as you have 'learned from your mistakes'

3. Do not understand the answer - if this is the case you **must** seek assistance from your teacher (if you do not then you will ***never*** understand this and this may be a building block for later work!)

When you’re confident with this topic move onto part 11:

Required practical !