| Centre Number | | | | | | Candidate Number | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Surname | | | | | | Other Names | | | | |

**Notice to Candidate.** The work you submit for assessment must be your own. If you copy from someone else or allow another candidate to copy from you, or if you cheat in any other way, you may be disqualified.

**Candidate Declaration.** I have read and understood the Notice to Candidate and can confirm that I have produced the attached work without assistance other than that which is acceptable under the scheme of assessment.

| Candidate Signature | | Date | |
|---|---|---|---|

| For Teacher's Use | |
|---|---|
| Section | Mark |
| PSA | |
| Task | |
| Section A | |
| Section B | |
| TOTAL ISA MARK (max 50) | |

General Certificate of Education
Advanced Subsidiary Examination
June 2013

# Chemistry CHM3T/P13/test

## Unit 3T AS Investigative Skills Assignment

## Written Test

## For submission by 15 May 2013

| **For this paper you must have:** | **Time allowed** |
|---|---|
| • the Periodic Table/Data Sheet provided at the end of this paper<br>• your Task Sheet and your Candidate Results Sheet<br>• a ruler with millimetre measurements<br>• a calculator. | • 1 hour |
| **Instructions** | **Information** |
| • Use black ink or black ball-point pen.<br>• Fill in the boxes at the top of this page.<br>• Answer **all** questions.<br>• You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.<br>• Do all rough work in this book. Cross through any work you do not want to be marked. | • The marks for questions are shown in brackets.<br>• The maximum mark for this paper is 30.<br>• You are expected to use a calculator, where appropriate.<br>• You will be marked on your ability to:<br>– organise information clearly<br>– use scientific terminology accurately. |

**Details of additional assistance (if any).** Did the candidate receive any help or information in the production of this work? If you answer yes give the details below or on a separate page.

Yes ☐ No ☐

**Teacher Declaration:**
I confirm that the candidate's work was conducted under the conditions laid out by the specification. I have authenticated the candidate's work and am satisfied that to the best of my knowledge the work produced is solely that of the candidate.

Signature of teacher ..... Date .....

**There are no questions printed on this page**

**DO NOT WRITE ON THIS PAGE**
**ANSWER IN THE SPACES PROVIDED**

## Section A

These questions are about the task, an investigation of the water of crystallisation in washing soda.

You should use your Task Sheet and your Candidate Results Sheet to answer these questions.

Answer **all** questions in the spaces provided.

**1** Record the average titre from your Candidate Results Sheet.

.....

*(1 mark)*

**2** The concentration of the hydrochloric acid used in the titration was 0.100 mol $dm^{-3}$.

Use your result from Question **1** to determine the amount, in moles, of hydrochloric acid in the average titre.

.....

.....

*(1 mark)*

**3** The equation for the reaction in the titration is

$$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2$$

Use this equation and your answer to Question **2** to calculate the amount, in moles, of sodium carbonate used in each titration.

.....

.....

*(1 mark)*

**4** Use your answer to Question **3** to calculate the concentration, in mol $dm^{-3}$, of sodium carbonate in solution **Y**.
Give your answer to the appropriate precision. Show your working.

.....

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*(3 marks)*

**Turn over ▶**

**5** Solution **Y** was made by dissolving 71.50 g of a sample of hydrated sodium carbonate in deionised water and making up to 5.00 $dm^3$ of solution.

**5 (a)** Use your answer to Question **4** to calculate the relative formula mass ($M_r$) of this hydrated sodium carbonate.
Show your working.
(If you were unable to complete the calculation in Question **4**, you may assume that the concentration of the sodium carbonate solution was 0.0487 mol $dm^{-3}$. This is **not** the correct value.)

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*(2 marks)*

**5 (b)** The formula of the hydrated sodium carbonate can be represented as $Na_2CO_3.xH_2O$

**5 (b) (i)** Use your value of $M_r$ from Question **5 (a)** to calculate a value for $x$
Give your answer to one decimal place.

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.....

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*(1 mark)*

**5 (b) (ii)** The $M_r$ of $Na_2CO_3.10H_2O$ is 286.0
The maximum percentage error in the experiment that can be due to the apparatus is ±1.0%. If the only error is apparatus error, calculate the minimum value of the $M_r$ of $Na_2CO_3.10H_2O$ that could be obtained from an experiment.

Use this minimum value of the $M_r$ to calculate a minimum experimental value for $x$
Give your answer to one decimal place.

Minimum value of $M_r$ .....

.....

Minimum value of $x$ .....

.....

*(2 marks)*

*Do not write outside the box*

**5 (c)** A similar titration was carried out with a different sample of pure washing soda that had been stored for some time. A student obtained a value of 8.6 for the value of *x*. The container from which the hydrated sodium carbonate was taken was labelled $Na_2CO_3.10H_2O$

Assume that the student carried out the titration and the calculation accurately. State **one** reason why the number of moles of water of crystallisation is less than 10.

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.....

*(1 mark)*

**6** Another student carried out the Task and obtained a set of concordant results even though the procedure was not followed correctly. The student observed an immediate red colour when the indicator was added in step 3 of the procedure. At the end of the titration the correct orange solution was formed.

**6 (a)** Give **one** possible reason for these observations.

.....

.....

*(1 mark)*

**6 (b)** State how the results from this student's experiment could be used to calculate the relative formula mass of the hydrated sodium carbonate.

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*(1 mark)*

**7** Dilute solutions of sodium carbonate and hydrochloric acid are both classified as irritants. State the **essential** safety precaution to be taken when using these irritants.

.....

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*(1 mark)*

**15**

## Section B

Answer **all** questions in the spaces provided.

There is another experimental method for determining the number of water molecules in the formula of hydrated sodium carbonate. This method involves heating a sample to a temperature higher than 300 ºC and recording the change in mass of the sample. The equation for the reaction taking place is

$$Na_2CO_3.10H_2O(s) \longrightarrow Na_2CO_3(s) + 10H_2O(g)$$

**8** A group of six students carried out this experiment. They each weighed out a sample of hydrated sodium carbonate. They then heated their sample to a temperature higher than 300 ºC in a crucible for ten minutes and recorded the final mass after the crucible had cooled. Their results are summarised in the table.

| **Student** | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| **Initial mass / g** | 2.43 | 1.65 | 3.58 | 1.09 | 2.82 | 1.95 |
| **Final mass / g** | 0.90 | 0.61 | 1.53 | 0.40 | 1.15 | 0.72 |

**8 (a)** Plot the values of **Initial mass** (*y*-axis) against **Final mass** on the grid opposite.

A graph of these results should include an additional point.
Draw a circle on the grid around the additional point that you should include. *(4 marks)*

**8 (b)** Draw a best-fit straight line for these results that includes your additional point. *(1 mark)*

**8 (c)** Identify each student whose experiment gave an anomalous result.

.....

.....

*(1 mark)*

**8 (d)** All the students carried out the experiment exactly according to this method.
Explain why a student that you identified in Question **8 (c)** obtained an anomalous result.

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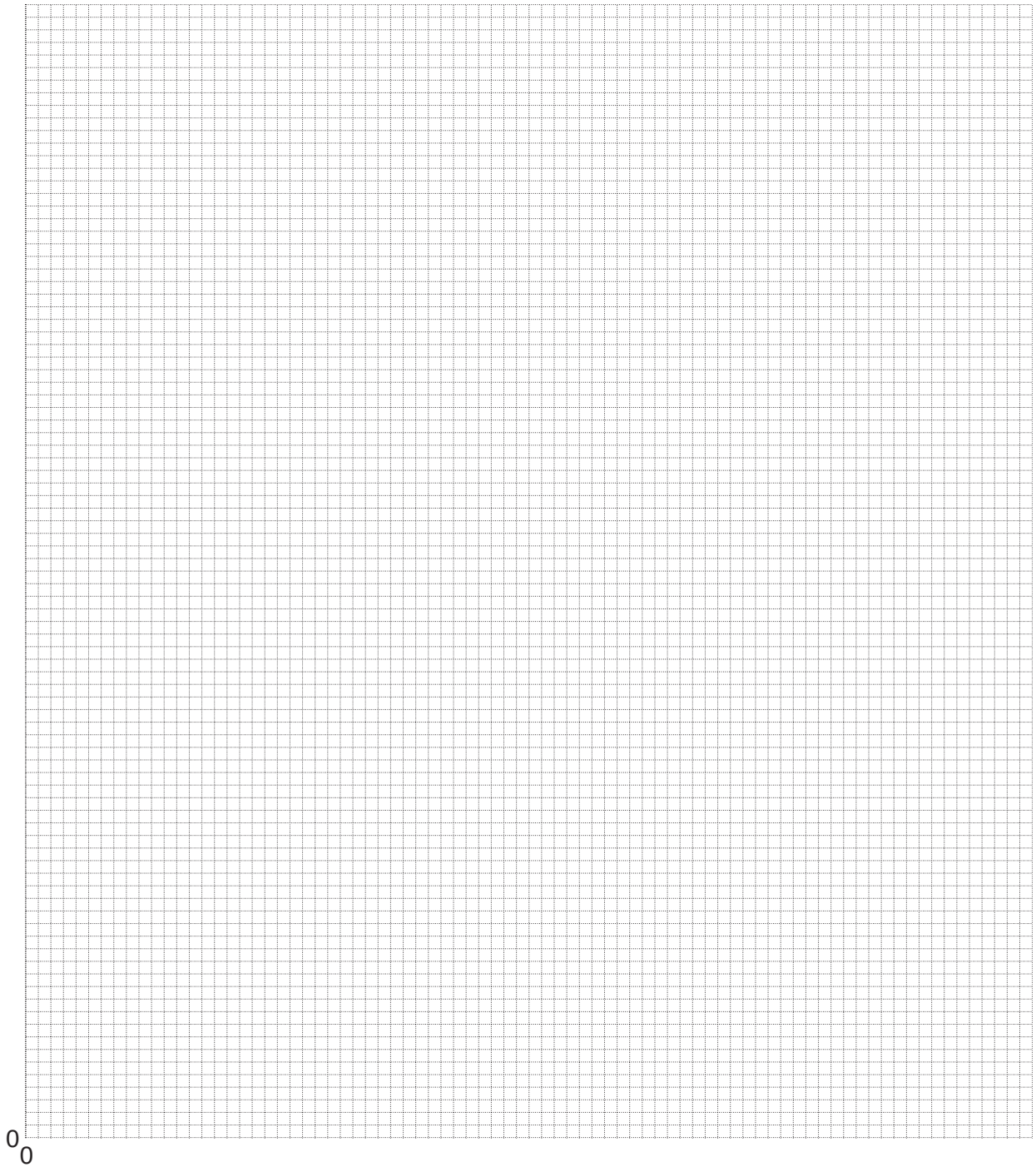
*(2 marks)*

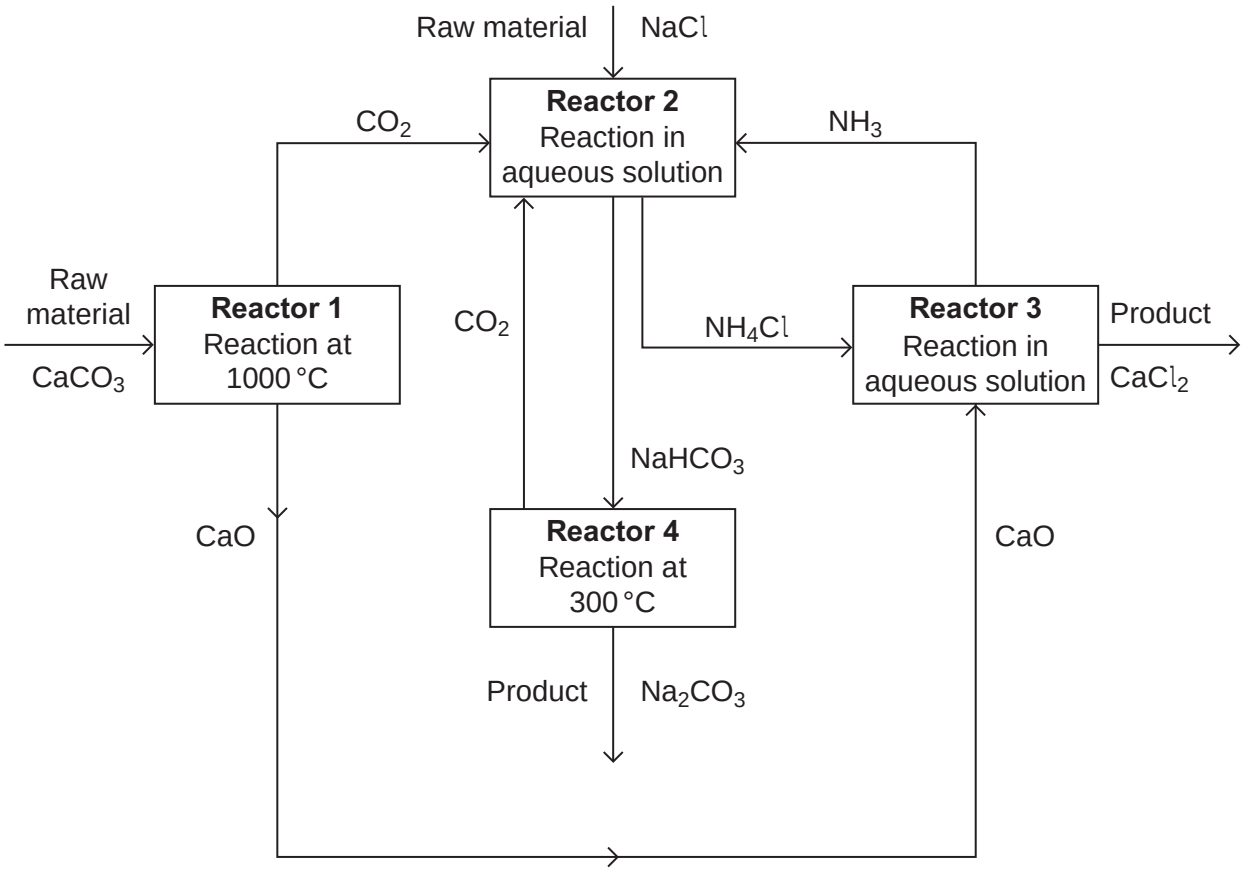
*Do not write outside the box*




**Turn over for the next question**

**9** Sodium carbonate is manufactured by the Solvay Process.

The separate stages involved in this process are shown in this diagram.




**9 (a)** In **Reactor 1**, calcium carbonate is decomposed into calcium oxide and carbon dioxide. Despite no significant leakage of carbon dioxide from this decomposition, this part of the process results in an increase in carbon dioxide in the atmosphere.

State why this increase in carbon dioxide occurs.

.....

.....

*(1 mark)*

**9 (b)** In **Reactor 2**, sodium chloride solution, carbon dioxide and ammonia react to form sodium hydrogencarbonate and ammonium chloride.

Write an equation for this reaction.

.....

*(1 mark)*

**9 (c)** Use information from the diagram to deduce an equation for the reaction taking place in **Reactor 3**.

.....

.....

*(1 mark)*

**9 (d)** An equation for the overall reaction in the Solvay Process is

$$2NaCl(aq) + CaCO_3(s) \longrightarrow Na_2CO_3(s) + CaCl_2(aq)$$

**9 (d) (i)** Calculate the percentage atom economy of this reaction to produce sodium carbonate. Show your working.

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.....

.....

*(2 marks)*

**9 (d) (ii)** State what could be done to improve the percentage atom economy of the Solvay Process.

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*(1 mark)*

**9 (e)** Use information from the diagram to suggest why ammonia is **not** regarded as a raw material in the Solvay Process.

.....

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*(1 mark)*

15

**END OF QUESTIONS**

**Table 1**

Infrared absorption data

| Bond | Wavenumber /cm$^{-1}$ |
|---|---|
| N — H (amines) | 3300 – 3500 |
| O — H (alcohols) | 3230 – 3550 |
| C — H | 2850 – 3300 |
| O — H (acids) | 2500 – 3000 |
| C ≡ N | 2220 – 2260 |
| C = O | 1680 – 1750 |
| C = C | 1620 – 1680 |
| C — O | 1000 – 1300 |
| C — C | 750 – 1100 |

**Table 2**

$^{1}$H n.m.r. chemical shift data

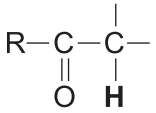
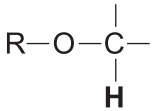
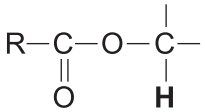
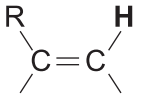
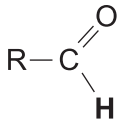
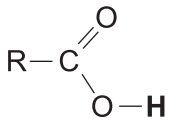
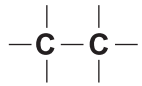
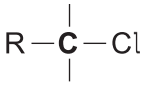
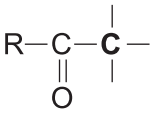
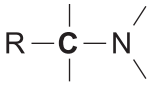
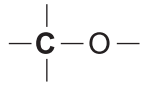
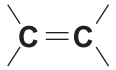
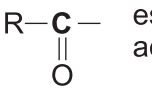
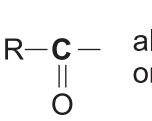
| Type of proton | δ/ppm |
|---|---|
| ROH | 0.5 – 5.0 |
| RCH$_3$ | 0.7 – 1.2 |
| RNH$_2$ | 1.0 – 4.5 |
| R$_2$CH$_2$ | 1.2 – 1.4 |
| R$_3$CH | 1.4 – 1.6 |
|  | 2.1 – 2.6 |
|  | 3.1 – 3.9 |
| RCH$_2$Cl or Br | 3.1 – 4.2 |
|  | 3.7 – 4.1 |
|  | 4.5 – 6.0 |
|  | 9.0 – 10.0 |
|  | 10.0 – 12.0 |

**Table 3**

$^{13}$C n.m.r. chemical shift data

| Type of carbon | δ/ppm |
|---|---|
|  | 5 – 40 |
|  | 10 – 70 |
|  | 20 – 50 |
|  | 25 – 60 |
|  alcohols, ethers or esters | 50 – 90 |
|  | 90 – 150 |
|  | 110 – 125 |
|  | 110 – 160 |
|  esters or acids | 160 – 185 |
|  aldehydes or ketones | 190 – 220 |

# The Periodic Table of the Elements

| 1 | 2 | | | | | | | | | | | 3 | 4 | 5 | 6 | 7 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | | | | | | | | | | | (13) | (14) | (15) | (16) | (17) | (18) |
| 6.9 **Li** lithium 3 | 9.0 **Be** beryllium 4 | | | | | | 1.0 **H** hydrogen 1 | | | | | 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 | 4.0 **He** helium 2 |
| 23.0 **Na** sodium 11 | 24.3 **Mg** magnesium 12 | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (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 | 20.2 **Ne** neon 10 |
| 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 | [98] **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 | [268] **Db** dubnium 105 | [271] **Sg** seaborgium 106 | [272] **Bh** bohrium 107 | [270] **Hs** hassium 108 | [276] **Mt** meitnerium 109 | [281] **Ds** darmstadtium 110 | [280] **Rg** roentgenium 111 | Elements with atomic numbers 112-116 have been reported but not fully authenticated | | | | | | |

**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 | 173.1 **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