



Rewarding Learning

**ADVANCED**  
**General Certificate of Education**  
**2018**

Centre Number

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Candidate Number

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# Chemistry

Assessment Unit A2 2

*assessing*

Analytical, Transition Metals,  
 Electrochemistry and Further  
 Organic Chemistry

**[AC222]**

\*AC222\*

**TUESDAY 12 JUNE, AFTERNOON**

## TIME

2 hours.

## INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.

Answer **all fifteen** questions.

Answer **all ten** questions in **Section A**. Record your answers by marking the appropriate letter on the answer sheet provided. Use only the spaces numbered 1 to 10. Keep in sequence when answering.

Answer **all five** questions in **Section B**. **You must answer the questions in the spaces provided.**

**Do not write outside the boxed area on each page or on blank pages.**

Complete in black ink only. **Do not write with a gel pen.**

## INFORMATION FOR CANDIDATES

The total mark for this paper is 120.

Quality of written communication will be assessed in Question **12(f)(i)**.

In Section A all questions carry equal marks, i.e. **two** marks for each question.

In Section B the figures printed down the right-hand side of pages indicate the marks awarded to each question or part question.

A Periodic Table of the Elements, containing some data, is included in this question paper.

11467.03R



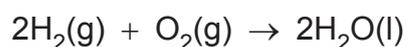
\*20AC22201\*

## Section A

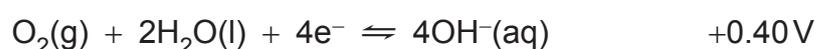
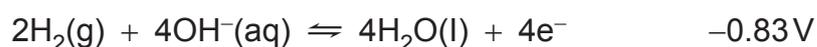
For each of the following questions only **one** of the lettered responses (A–D) is correct.

**Select the correct response in each case and mark its code letter by connecting the dots as illustrated on the answer sheet.**

**1** In a fuel cell the following reaction takes place:



The relevant standard electrode potentials are:

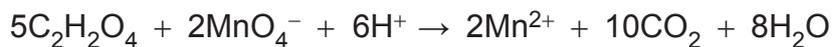


The emf of the fuel cell is

- A  $-0.43\text{V}$ .
  - B  $+0.43\text{V}$ .
  - C  $-1.23\text{V}$ .
  - D  $+1.23\text{V}$ .
- 2** Which one of the following ligands is regarded as a large ligand?
- A  $\text{Cl}^-$
  - B  $\text{H}_2\text{O}$
  - C  $\text{NH}_3$
  - D  $\text{OH}^-$



- 3 Ethanedioic acid reacts with manganate(VII) ions according to the following equation:



25 cm<sup>3</sup> of 0.015 M manganate(VII) ions were added to 25 cm<sup>3</sup> of 0.0208 M ethanedioic acid. Which one of the following is the number of moles of carbon dioxide produced?

- A  $3.75 \times 10^{-4}$   
B  $5.2 \times 10^{-4}$   
C  $1.04 \times 10^{-3}$   
D  $1.88 \times 10^{-3}$

- 4 Which one of the following does **not** take place during heterogeneous catalysis by transition metals?

- A Absorption  
B Bonds breaking  
C Desorption  
D d-orbital interaction

- 5 A standard hydrogen electrode operates

- A at 20 °C.  
B at a pressure of 1 atmosphere of hydrogen gas.  
C using molar sulfuric acid.  
D with platinum-palladium electrodes.

[Turn over

11467.03R



- 6 When methylbenzoate is nitrated the product is
- A methyl 1-nitrobenzoate.
  - B methyl-1-nitrobenzoate.
  - C methyl 3-nitrobenzoate.
  - D methyl-3-nitrobenzoate.
- 7 In a plane, the emergency oxygen system is based on sodium chlorate(V) which decomposes to give oxygen and sodium chloride when heated. A human under stress uses  $38.0 \text{ dm}^3$  of oxygen every 15 minutes. Assuming the oxygen is measured at  $20^\circ\text{C}$  and 1 atmosphere pressure, what is the minimum mass of sodium chlorate(V) needed in the emergency oxygen system to supply 15 minutes of oxygen for one person?
- A 56 g
  - B 112 g
  - C 224 g
  - D 336 g
- 8 Which one of the following vanadium ions is green?
- A  $\text{V}^{2+}(\text{aq})$
  - B  $\text{V}^{3+}(\text{aq})$
  - C  $\text{VO}^{2+}(\text{aq})$
  - D  $\text{VO}_2^+(\text{aq})$



9 In which one of the following compounds does manganese show the lowest oxidation state?

- A  $\text{KMnO}_4$
- B  $\text{K}_2\text{MnO}_4$
- C  $\text{Mn}_2\text{O}_7$
- D  $\text{Mn}(\text{CH}_3\text{CO}_2)_2 \cdot 4\text{H}_2\text{O}$

10 Which one of the following molecules is **not** optically active?

- A  $\text{BrCH}_2\text{CH}(\text{OH})\text{CH}_2\text{Br}$
- B  $\text{CH}_3\text{CHBrCH}_2\text{Br}$
- C  $\text{CH}_3\text{CH}(\text{CH}_3)\text{CHBrCH}_3$
- D  $\text{BrCH}_2\text{CH}(\text{CH}_3)\text{CH}_2\text{OH}$



**Section B**

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

**11 (a)** Explain the following terms which are used in nmr spectroscopy.

**(i)** Low resolution nmr spectrum.

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[1]

**(ii)** Chemically equivalent hydrogen atoms.

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[1]

**(iii)** Chemical shift.

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[1]

**(iv)** Integration curve.

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[2]

**(v)** The  $n + 1$  rule.

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[2]



(b) Suggest how you would prepare a solution of a compound for nmr analysis. Name a solvent that would not interfere with the spectrum and name a substance that could be used as a standard.

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[3]

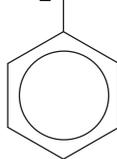
[Turn over

11467.03R



\*20AC22207\*

- 12 Phenibut was first synthesised in Russia and was used by cosmonauts because it relieved anxiety and depression without causing drowsiness.



Phenibut

- (a) Assuming that the benzene ring is regarded as a phenyl group, suggest a systematic name for phenibut.

\_\_\_\_\_ [2]

- (b) The structure of phenibut reveals that it is an amino acid. Suggest why it is not found in proteins.

\_\_\_\_\_  
\_\_\_\_\_ [1]

- (c) Phenibut has a melting point of 253 °C. Explain why phenibut has such a high melting point.

\_\_\_\_\_  
\_\_\_\_\_ [2]



(d) Phenibut reacts with nitrous acid, methanol, sodium hydrogencarbonate and ethanoyl chloride. Write equations for the reactions.

(i) nitrous acid

\_\_\_\_\_ [2]

(ii) methanol

\_\_\_\_\_ [2]

(iii) sodium hydrogencarbonate

\_\_\_\_\_ [2]

(iv) ethanoyl chloride

\_\_\_\_\_ [2]

[Turn over

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(e) Phenibut is an optically active molecule. When used as a mixture of the optical isomers, only one of the isomers is biologically active.

(i) Explain the meaning of the term **optically active**.

\_\_\_\_\_  
\_\_\_\_\_ [2]

(ii) Explain, using the structure of phenibut, why it is optically active.

\_\_\_\_\_  
\_\_\_\_\_ [2]

(iii) Suggest why only one of the optically active molecules is biologically active.

\_\_\_\_\_  
\_\_\_\_\_ [2]

(f) Phenibut is very soluble in both ethanol and water. If sodium hydroxide solution is added to an aqueous solution of impure phenibut the sodium salt is formed.

(i) Explain, giving practical details, how you could obtain a pure sample of phenibut crystals from the aqueous sodium salt.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_ [5]

Quality of written communication [2]



(ii) Explain, giving full experimental directions, how you would use TLC to compare the purity of the phenibut before and after purification.

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[4]

(iii) Explain whether TLC would enable you to show that phenibut consisted of two optical isomers.

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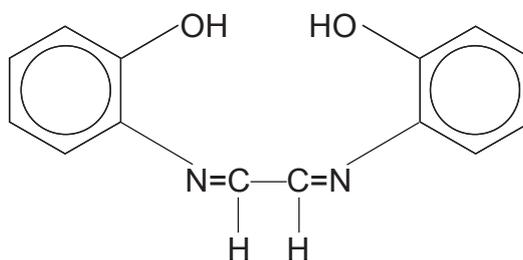
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[2]



- 13 The cations of the Group II elements form only a limited number of complexes in aqueous solution. Edta has been widely used in the complexometric titration of these ions but the end point is difficult to observe. However, calcium can also be determined in microgram quantities using the glyoxalin complex.



glyoxalin complex

The intensity of the pink colour of its complex is a measure of how much  $\text{Ca}^{2+}$  is present and is determined by a colorimeter.

- (a) (i) Explain how you would carry out an edta titration for  $\text{Ca}^{2+}$  stating the indicator used, what the pH is adjusted to and the colour change at the end point. Routine aspects of practical titration are not needed.

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[4]

- (ii) 0.4505 g of calcium carbonate was dissolved in hydrochloric acid and the solution made up to  $250 \text{ cm}^3$  in a volumetric flask. A  $25 \text{ cm}^3$  sample of the solution required  $24.25 \text{ cm}^3$  of an edta solution for titration. Calculate the molar concentration of the edta solution in  $\text{mol dm}^{-3}$ .

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[3]



(iii) Edta is a hexadentate ligand. What type of ligand is the glyoxalin complex?

\_\_\_\_\_ [1]

(b) The compound formed by  $\text{Ca}^{2+}$  with the glyoxalin complex is pink and is insoluble in water but dissolves in butan-1-ol. The mass of calcium in a sample is determined by adding a buffer solution, the glyoxalin complex and butan-1-ol to the solution of calcium ions.

(i) The mixture is shaken and becomes homogeneous. Explain why the mixture becomes homogeneous.

\_\_\_\_\_ [1]

(ii) Explain why a green filter is used in the colorimeter.

\_\_\_\_\_ [2]

(iii) Deionised water is used as a **reference** solution. Explain what this term means.

\_\_\_\_\_ [1]

(iv) A calibration curve is needed to determine the amount of calcium ions in solution. Explain how you would experimentally determine a calibration curve.

\_\_\_\_\_ [3]

[Turn over

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\*20AC22213\*

14 The benzene ring is stable to the addition of halogens. Halogens normally react with double bonds by adding to them; however with a benzene ring they react by substitution. The substitution reaction is speeded up using a catalyst.

(a) Explain why halogens are more reactive with alkenes than with benzene.

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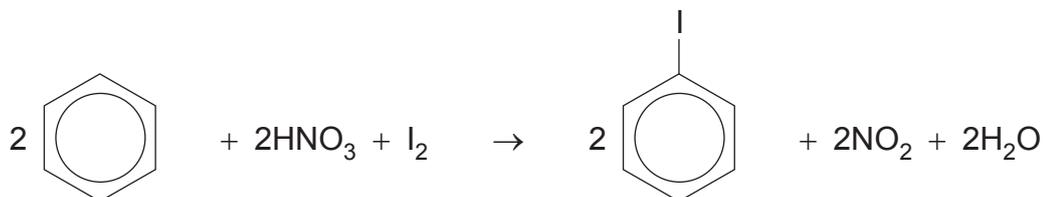
[2]

(b) Draw a flow scheme for the mechanism of the bromination of benzene using a catalyst such as iron(III) bromide.

[4]



- (c) The iodination of benzene does not take place with iodine at room temperature. However, it is formed by refluxing benzene with iodine and concentrated nitric acid.



- (i) Explain, using oxidation numbers, the redox reaction taking place.

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[3]

- (ii) The electrophile in this reaction is the iodonium ion. Write the formula of the iodonium ion and give the definition of an **electrophile**.

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[3]

- (iii) Explain why nitric acid is not regarded as a catalyst in this reaction.

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[1]

[Turn over

11467.03R



\*20AC22215\*

(d) The preparation of iodobenzene using concentrated nitric acid is time consuming, dangerous and expensive. It is better prepared using the Sandmeyer reaction which involves the diazotisation of phenylamine.

(i) Explain why the preparation of iodobenzene is dangerous.

\_\_\_\_\_  
\_\_\_\_\_ [1]

(ii) Explain, giving experimental details, how you would diazotise phenylamine.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_ [3]

(iii) Explain why the benzenediazonium ion is relatively stable at low temperature and why it decomposes at higher temperatures.

\_\_\_\_\_  
\_\_\_\_\_ [2]

(iv) Name the reagent used to convert benzenediazonium chloride to iodobenzene.

\_\_\_\_\_  
\_\_\_\_\_ [1]

(v) Write the overall equation for the conversion of benzenediazonium chloride to iodobenzene.

\_\_\_\_\_ [2]



(e) The boiling points of the halogenobenzenes are shown below.

Bromobenzene            156 °C

Chlorobenzene           131 °C

Iodobenzene             188 °C

(i) Explain which of the halogenobenzenes you would expect to have the highest polarity.

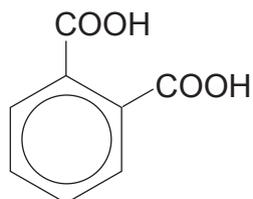
\_\_\_\_\_ [2]

(ii) Explain why iodobenzene has the highest boiling point.

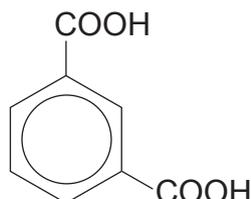
\_\_\_\_\_ [2]



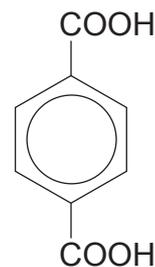
15 There are three benzene dicarboxylic acids.



A



B



C

(a) Suggest why acid B has the highest boiling point.

\_\_\_\_\_ [1]

(b) The French chemist Caillot obtained terephthalic acid, C, by the oxidation of turpentine (turpentine = terebenthine in French). Today it is obtained by the oxidation of 1,4-dimethylbenzene.

(i) Write the equation for the oxidation of 1,4-dimethylbenzene to form terephthalic acid using [O] as the oxidising agent.

\_\_\_\_\_ [2]

(ii) Terephthalic acid is purified using its dimethyl ester. Write the equation for the formation of the dimethyl ester from the acid.

\_\_\_\_\_ [2]

(iii) The dimethyl ester is formed during the recycling of polyethylene terephthalate from plastic bottles. Explain why it is useful to form the ester to help the recycling process.

\_\_\_\_\_ [2]



(c) The major use of terephthalic acid is in the production of the polymer polyethylene terephthalate (PET).

(i) Draw the repeating structure of PET.

[2]

(ii) PET can be hydrolysed both in nature and in industry. Compare the two methods, stating the conditions used in each case.

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[4]

(iii) PET is an exceptional polymer because it has high **crystallinity** and no **branching**. Explain the meaning of these terms with regard to PET.

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[3]

(d) Suggest why polythene bags are often burnt rather than recycled.

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[1]

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| For Examiner's use only |       |
|-------------------------|-------|
| Question Number         | Marks |
| Section A               |       |
| 1–10                    |       |
| Section B               |       |
| 11                      |       |
| 12                      |       |
| 13                      |       |
| 14                      |       |
| 15                      |       |
| <b>Total Marks</b>      |       |

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234716



\*20AC22220\*

## **Periodic Table of the Elements**

For the use of candidates taking  
Advanced Subsidiary and Advanced Level  
Chemistry Examinations

**Copies must be free from notes or additions of any  
kind. No other type of data booklet or information  
sheet is authorised for use in the examinations.**

**gce A/AS examinations**  
**chemistry**  
**(advanced)**

| I                                  | II   | THE PERIODIC TABLE OF ELEMENTS<br>Group |                                    |                                    |                                     |                                     |                                     |                                   |                                     |                                  |                                    | III                                | IV                                 | V                                  | VI                                  | VII                                | 0                                |                                    |                                  |                                    |                                |                                     |                                |
|------------------------------------|--|---|------------------------------------|------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-----------------------------------|-------------------------------------|----------------------------------|------------------------------------|------------------------------------|------------------------------------|------------------------------------|-------------------------------------|------------------------------------|----------------------------------|------------------------------------|----------------------------------|------------------------------------|--------------------------------|-------------------------------------|--------------------------------|
| 1<br><b>H</b><br>Hydrogen<br>1     | One mole of any gas at 20°C and a pressure of 1 atmosphere (10 <sup>5</sup> Pa) occupies a volume of 24 dm <sup>3</sup> .<br>Planck Constant = 6.63 × 10 <sup>-34</sup> Js<br>Gas Constant = 8.31 J mol <sup>-1</sup> K <sup>-1</sup><br>Avogadro Constant = 6.02 × 10 <sup>23</sup> mol <sup>-1</sup> |   |                                    |                                    |                                     |                                     |                                     |                                   |                                     |                                  |                                    |                                    |                                    |                                    |                                     |                                    | 4<br><b>He</b><br>Helium<br>2    |                                    |                                  |                                    |                                |                                     |                                |
| 7<br><b>Li</b><br>Lithium<br>3     |  |   |                                    |                                    |                                     |                                     |                                     |                                   |                                     |                                  | 9<br><b>Be</b><br>Beryllium<br>4   |                                    |                                    |                                    |                                     |                                    |                                  | 11<br><b>B</b><br>Boron<br>5       | 12<br><b>C</b><br>Carbon<br>6    | 14<br><b>N</b><br>Nitrogen<br>7    | 16<br><b>O</b><br>Oxygen<br>8  | 19<br><b>F</b><br>Fluorine<br>9     | 20<br><b>Ne</b><br>Neon<br>10  |
| 23<br><b>Na</b><br>Sodium<br>11    |  |   |                                    |                                    |                                     |                                     |                                     |                                   |                                     |                                  | 24<br><b>Mg</b><br>Magnesium<br>12 |                                    |                                    |                                    |                                     |                                    |                                  | 27<br><b>Al</b><br>Aluminium<br>13 | 28<br><b>Si</b><br>Silicon<br>14 | 31<br><b>P</b><br>Phosphorus<br>15 | 32<br><b>S</b><br>Sulfur<br>16 | 35.5<br><b>Cl</b><br>Chlorine<br>17 | 40<br><b>Ar</b><br>Argon<br>18 |
| 39<br><b>K</b><br>Potassium<br>19  | 40<br><b>Ca</b><br>Calcium<br>20   | 45<br><b>Sc</b><br>Scandium<br>21       | 48<br><b>Ti</b><br>Titanium<br>22  | 51<br><b>V</b><br>Vanadium<br>23   | 52<br><b>Cr</b><br>Chromium<br>24   | 55<br><b>Mn</b><br>Manganese<br>25  | 56<br><b>Fe</b><br>Iron<br>26       | 59<br><b>Co</b><br>Cobalt<br>27   | 59<br><b>Ni</b><br>Nickel<br>28     | 64<br><b>Cu</b><br>Copper<br>29  | 65<br><b>Zn</b><br>Zinc<br>30      | 70<br><b>Ga</b><br>Gallium<br>31   | 73<br><b>Ge</b><br>Germanium<br>32 | 75<br><b>As</b><br>Arsenic<br>33   | 79<br><b>Se</b><br>Selenium<br>34   | 80<br><b>Br</b><br>Bromine<br>35   | 84<br><b>Kr</b><br>Krypton<br>36 |                                    |                                  |                                    |                                |                                     |                                |
| 85<br><b>Rb</b><br>Rubidium<br>37  | 88<br><b>Sr</b><br>Strontium<br>38   | 89<br><b>Y</b><br>Yttrium<br>39         | 91<br><b>Zr</b><br>Zirconium<br>40 | 93<br><b>Nb</b><br>Niobium<br>41   | 96<br><b>Mo</b><br>Molybdenum<br>42 | 99<br><b>Tc</b><br>Technetium<br>43 | 101<br><b>Ru</b><br>Ruthenium<br>44 | 103<br><b>Rh</b><br>Rhodium<br>45 | 106<br><b>Pd</b><br>Palladium<br>46 | 108<br><b>Ag</b><br>Silver<br>47 | 112<br><b>Cd</b><br>Cadmium<br>48  | 115<br><b>In</b><br>Indium<br>49   | 119<br><b>Sn</b><br>Tin<br>50      | 122<br><b>Sb</b><br>Antimony<br>51 | 128<br><b>Te</b><br>Tellurium<br>52 | 127<br><b>I</b><br>Iodine<br>53    | 131<br><b>Xe</b><br>Xenon<br>54  |                                    |                                  |                                    |                                |                                     |                                |
| 133<br><b>Cs</b><br>Caesium<br>55  | 137<br><b>Ba</b><br>Barium<br>56   | 139<br><b>La</b> *<br>Lanthanum<br>57   | 178<br><b>Hf</b><br>Hafnium<br>72  | 181<br><b>Ta</b><br>Tantalum<br>73 | 184<br><b>W</b><br>Tungsten<br>74   | 186<br><b>Re</b><br>Rhenium<br>75   | 190<br><b>Os</b><br>Osmium<br>76    | 192<br><b>Ir</b><br>Iridium<br>77 | 195<br><b>Pt</b><br>Platinum<br>78  | 197<br><b>Au</b><br>Gold<br>79   | 201<br><b>Hg</b><br>Mercury<br>80  | 204<br><b>Tl</b><br>Thallium<br>81 | 207<br><b>Pb</b><br>Lead<br>82     | 209<br><b>Bi</b><br>Bismuth<br>83  | 210<br><b>Po</b><br>Polonium<br>84  | 210<br><b>At</b><br>Astatine<br>85 | 222<br><b>Rn</b><br>Radon<br>86  |                                    |                                  |                                    |                                |                                     |                                |
| 223<br><b>Fr</b><br>Francium<br>87 | 226<br><b>Ra</b><br>Radium<br>88   | 227<br><b>Ac</b> †<br>Actinium<br>89    |                                    |                                    |                                     |                                     |                                     |                                   |                                     |                                  |                                    |                                    |                                    |                                    |                                     |                                    |                                  |                                    |                                  |                                    |                                |                                     |                                |

\* 58–71 Lanthanum series  
† 90–103 Actinium series

$\begin{matrix} a \\ b \end{matrix} x$  a = relative atomic mass (approx.)  
x = atomic symbol  
b = atomic number

|                                   |  |                                     |                                      |                                     |                                     |                                      |                                     |                                       |                                       |                                    |  |                                     |                                       |
|-----------------------------------|--|-------------------------------------|--------------------------------------|-------------------------------------|-------------------------------------|--------------------------------------|-------------------------------------|---------------------------------------|---------------------------------------|------------------------------------|--|-------------------------------------|---------------------------------------|
| 140<br><b>Ce</b><br>Cerium<br>58  | 141<br><b>Pr</b><br>Praseodymium<br>59 | 144<br><b>Nd</b><br>Neodymium<br>60 | 147<br><b>Pm</b><br>Promethium<br>61 | 150<br><b>Sm</b><br>Samarium<br>62  | 152<br><b>Eu</b><br>Europium<br>63  | 157<br><b>Gd</b><br>Gadolinium<br>64 | 159<br><b>Tb</b><br>Terbium<br>65   | 162<br><b>Dy</b><br>Dysprosium<br>66  | 165<br><b>Ho</b><br>Holmium<br>67     | 167<br><b>Er</b><br>Erbium<br>68   | 169<br><b>Tm</b><br>Thulium<br>69      | 173<br><b>Yb</b><br>Ytterbium<br>70 | 175<br><b>Lu</b><br>Lutetium<br>71    |
| 232<br><b>Th</b><br>Thorium<br>90 | 231<br><b>Pa</b><br>Protactinium<br>91 | 238<br><b>U</b><br>Uranium<br>92    | 237<br><b>Np</b><br>Neptunium<br>93  | 242<br><b>Pu</b><br>Plutonium<br>94 | 243<br><b>Am</b><br>Americium<br>95 | 247<br><b>Cm</b><br>Curium<br>96     | 245<br><b>Bk</b><br>Berkelium<br>97 | 251<br><b>Cf</b><br>Californium<br>98 | 254<br><b>Es</b><br>Einsteinium<br>99 | 253<br><b>Fm</b><br>Fermium<br>100 | 256<br><b>Md</b><br>Mendelevium<br>101 | 254<br><b>No</b><br>Nobelium<br>102 | 257<br><b>Lr</b><br>Lawrencium<br>103 |