MATRICULATION AND SECONDARY EDUCATION CERTIFICATE EXAMINATIONS BOARD

UNIVERSITY OF MALTA, MSIDA

MATRICULATION EXAMINATION
INTERMEDIATE LEVEL
MAY 2015

SUBJECT:	CHEMISTRY
DATE:	29th April 2015
TIME:	9.00 a.m. to 12.00 noon

Useful information: The molar gas constant R = 8.31 J K^{-1} mol^{-1}
Relative atomic masses: H = 1, C = 12, O = 16

A Periodic Table is included.

Section A
Answer ALL questions in this Section

1. (a) Complete and balance the following equations:

$^{32}_{16}S + {}^{1}_{0}n \rightarrow {}^{32}_{15}P + {}^{A}_{Z}X$ A = _____ Z = _____ X = _____

$^{6}_{3}Li + {}^{1}_{0}n \rightarrow {}^{A}_{Z}H + {}^{4}_{2}\alpha$ A = _____ Z = _____

$^{14}_{6}C \rightarrow {}^{0}_{-1}e + {}^{A}_{Z}N$ A = _____ Z = _____

$^{1}_{1}p + {}^{14}_{7}N \rightarrow {}^{13}_{8}O + a\,{}^{A}_{Z}X$ a = _____ A = _____ Z = _____ X = _____

(4 marks)

(b) An initial sample contained 1000 atoms of $^{3}_{1}H$, having a half-life of 12 years. How long would it take for the given number of atoms to be reduced to 500 atoms?

_____

(1 mark)

(c) Radioactive carbon-14 is commonly used in industry. Give an example of **one** of its applications.

_____

(1 mark)
(Total: 6 marks)

2. In view of the *kinetic concept of the states of matter*, explain the following phenomena:

(a) Melting of a solid: _____

_____

_____

_____

(2 marks)

(b) Evaporation of a liquid: _____

_____

_____

_____

(2 marks)

(c) Diffusion of a gas: _____

_____

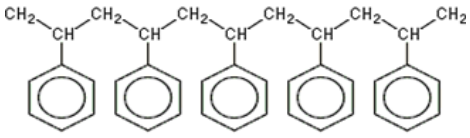
_____

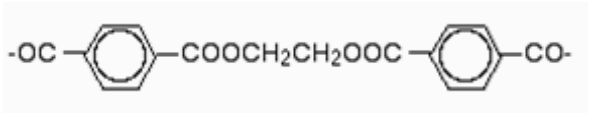
_____

(2 marks)

(Total: 6 marks)

3. (a) A *polymer* is a chain of repeating units. Given the polymers hereunder, **A** and **B**, indicate the *repeating unit* by drawing a rectangle around it.

A: 

B: 

(2 marks)

(b) Name the type of polymerisation reaction in each case.

Polymer **A**: _____

Polymer **B**: _____

(2 marks)

(Total: 4 marks)

4. **Underline** the correct term to complete the following statements.

(i) ***Going down*** Group I, the melting and boiling points of the elements **DECREASE / INCREASE**.

(1 mark)

(ii) ***Going up*** Group VII, the elements become better **OXIDISING / REDUCING** agents.

(1 mark)

(iii) ***Going down*** Group IV, the elements become **MORE / LESS** metallic.

(1 mark)

(iv) The elements in the top **RIGHT / LEFT** hand corner of the Periodic Table are non-metals.

(1 mark)

(v) Elements in Group VIII **DO / DO NOT** have a tendency to participate in chemical reactions.

(1 mark)

(Total: 5 marks)

5. Butan-1-ol has an isomer with molecular formula $C_2H_5OC_2H_5$.

(i) Name and give the structural formula of $C_2H_5OC_2H_5$.

(2 marks)

(ii) Are there any hydrogen bonds between the molecules of $C_2H_5OC_2H_5$? Explain briefly.

(2 marks)

(Total: 4 marks)

6. The elements sodium and chlorine react together to form the compound sodium chloride, which has a *giant ionic lattice structure*.

(a) Draw dot and cross diagrams to show how the electrons are arranged in a sodium ion and a chloride ion.

(2 marks)

(b) Give the electronic configuration (in terms of *spd* notation) of the sodium and chlorine atoms respectively.

(2 marks)

(Total: 4 marks)

7. Use the electron-pair repulsion model to predict the shape and the bond angles in the following molecules. Explain briefly.

(i) BF_3: _____

_____

_____

(2 marks)

(ii) NH_3: _____

_____

_____

(2 marks)

(iii) H_2O: _____

_____

_____

(2 marks)

(Total: 6 marks)

8. (a) State *Hess's Law of Constant Heat Summation*.

_____

_____

(2 marks)

(b) Calculate the *standard enthalpy of formation of benzene* using the following information:

$C\ (s) + O_2\ (g) \rightarrow CO_2\ (g)$	$\Delta H^{e}_{f} = -393.4\ KJ\ mol^{-1}$
$H_2\ (g) + \frac{1}{2}O_2\ (g) \rightarrow H_2O\ (l)$	$\Delta H^{e}_{f} = -285.8\ KJ\ mol^{-1}$
$C_6H_6\ (l) + 7\frac{1}{2}O_2\ (g) \rightarrow 6CO_2 + 3H_2O\ (l)$	$\Delta H^{e}_{c} = -3278\ KJ\ mol^{-1}$
$C_6H_{12}\ (l) + 9O_2\ (g) \rightarrow 6CO_2 + 6H_2O\ (l)$	$\Delta H^{e}_{c} = -3920\ KJ\ mol^{-1}$

_____

_____

_____

_____

_____

_____

(4 marks)

(Total: 6 marks)

9. (a) Define the term *relative atomic mass of an element* with respect to ^{12}C.

(2 marks)

(b) Element A has two isotopes, one with mass number 79 (50%) and one with mass number 81 (50%). Calculate the relative atomic mass of the element A.

(3 marks)
(Total: 5 marks)

10. (a) Define the term *electronegativity.*

(2 marks)

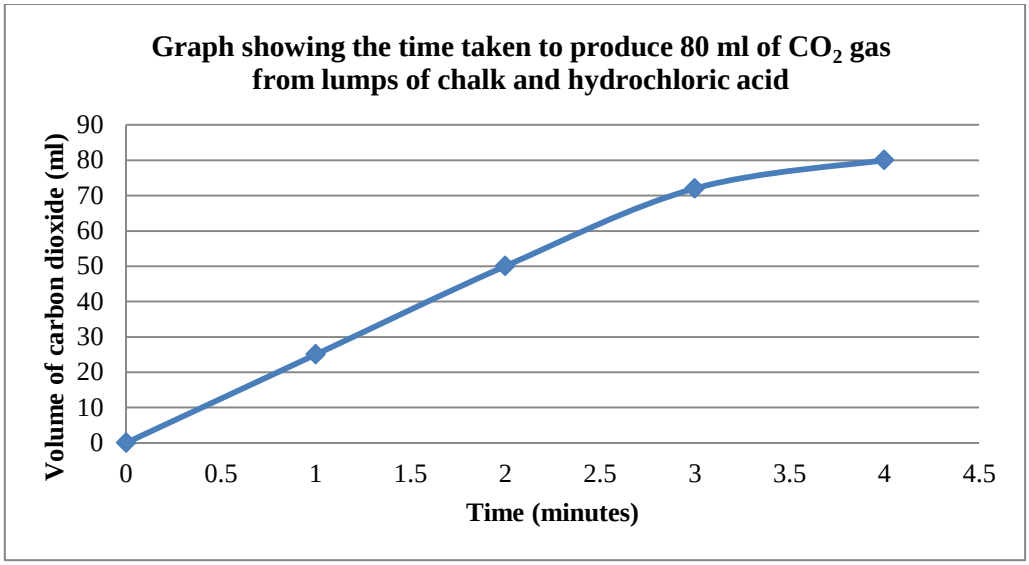
(b) Using the following electronegativity values, arrange the following compounds in order of *increasing ionic character.* Explain your reasoning.

CO_2, LiCl, MgF_2, NaCl, NH_3, S_2Cl_2

C = 2.5	O = 3.5	Li = 1.0	Mg = 1.2	Na = 0.9	N = 3.0
S = 2.5	Cl = 3.0	F = 4.0	Cl = 3.0	H = 2.1	

(4 marks)
(Total: 6 marks)

11.



(a) The data in the graph shows the time taken to produce 80 cm^3 of carbon dioxide gas from lumps of chalk and hydrochloric acid. Comment on the rate of reaction.

_____

_____

_____

_____

(2 marks)

(b) List **three** factors, other than by adding a catalyst, that can influence the rate of the chemical reaction without changing the volume of gas produced. Explain your reasoning.

_____

_____

_____

_____

_____

_____

_____

_____

(3 marks)

(Total: 5 marks)

12. (a) *Catenation* is prevalent in carbon compounds. Define the term *catenation* and explain its significance.

_____

_____

_____

_____

(2 marks)

(b) Butane is an organic compound with formula C_4H_{10}, commonly used as a fuel. Butane has one *structural isomer*. Answer the following questions about its chemistry.

(i) To which *homologous series* does butane belong?

_____

(1 mark)

(ii) Define the term *structural isomer.*

_____

_____

_____

(2 marks)

(iii) Draw the structural formula of the structural isomer of butane.

(1 mark)

(Total: 6 marks)

13. Alcohols **A**, **B**, and **C** are branched-chain isomers of pentan-2-ol.

- **A** cannot be oxidised by acidified potassium dichromate, $H^+/Cr_2O_7^{2-}$.
- **B** can be oxidised by $H^+/Cr_2O_7^{2-}$ but cannot be dehydrated.
- **C** can be oxidised by $H^+/Cr_2O_7^{2-}$ and can also be dehydrated.

Draw a possible structure for each of the three alcohols. Explain you reasoning.

Alcohol **A**: _____

_____

_____

_____

_____

(2 marks)

Alcohol **B**: _____

_____

_____

_____

_____

(2 marks)

Alcohol **C**: _____

_____

_____

_____

_____

(2 marks)

(Total: 6 marks)

14. In their majority, industrial reactions usually take place at high pressures, high temperatures and in the presence of a catalyst. Answer the following questions concerning the industrial preparation of ammonia.

(i) Give a balanced chemical equation of the Haber Process. Include state symbols.

_____

(2 marks)

(ii) Given that the enthalpy of the reaction is -92 KJ mol^{-1} would a *low* or *high* temperature favour the formation of ammonia? Explain your reasoning.

_____

_____

_____

(2 marks)

(iii) Analyse whether a high pressure would lead to more ammonia being produced.

_____

_____

_____

(2 marks)

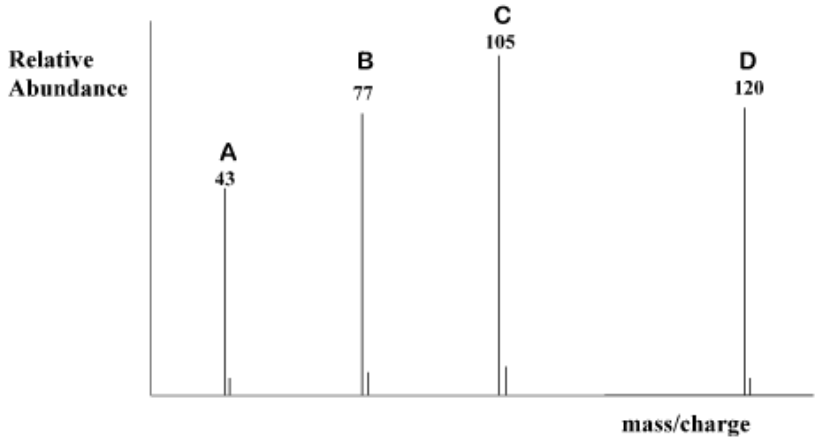
(Total: 6 marks)

15. (a) State **one** use of a mass spectrophotometer.

_____

(1 mark)

(b) The simplified mass spectrum below shows a number of fragments of the organic compound 1-phenylethanone ($CH_3 - CO - C_6H_5$). Deduce the formulae of the ions responsible for the given peaks.



A: _____

B: _____

C: _____

D: _____

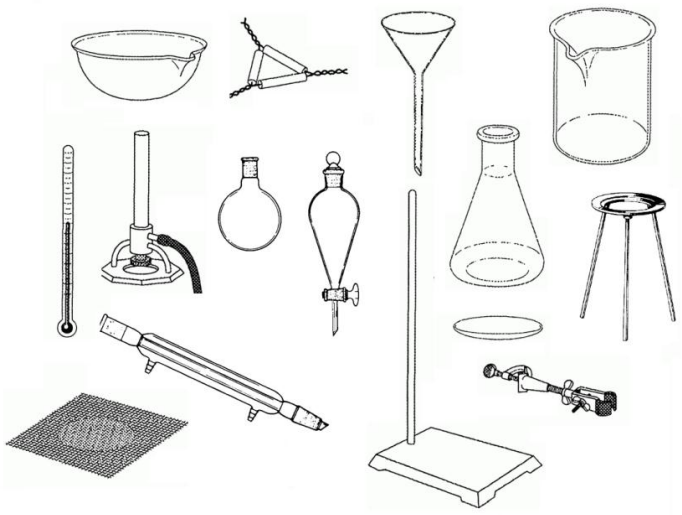
(4 marks)

(Total: 5 marks)

DO NOT WRITE ABOVE THIS LINE

Section B
Answer ALL questions in this Section

16. (a) Below are several pieces of apparatus. Fill in the table hereunder as required. The apparatus required for each separating technique may be used more than once.



Separating Techniques	Apparatus	Application
Filtration	(2 marks)	(1 mark)
(1 mark)	stand and clamp, Bunsen burner, tripod, wire gauze (or clay triangle), round-bottomed flask, Liebig condenser, thermometer, conical flask or beaker	(1 mark)
(1 mark)	(2 marks)	separating a solid that is dissolved in a liquid, forming a solution

(b) Draw a labelled diagram of the separating technique that could be used in the laboratory to separate the mixture of pigments in pen ink.

(6 marks)

(c) List **two** ways by which the *purity* of prepared substances could be determined.

_____

_____

(2 marks)
(Total: 16 marks)

17. Some labels have come off containers containing inorganic chemicals at a laboratory. The chemicals are *potassium chloride*, *copper carbonate*, *sodium sulfate* and *sodium nitrate*, but they have now been labelled **A, B, C** and **D.**
Answer the following questions to identify these chemicals and dispose of them correctly.

(a) Which striking feature will allow you to identify one compound amongst the rest? Which compound is it?

_____

_____

(2 marks)

(b) (i) Describe the test you would carry out to identify the **positive** ions in the unknown samples. Illustrate your description by drawing a labelled diagram of the setup of the apparatus. Outline the chemical principles involved.

_____

_____

_____

_____

(4 marks)

(ii) Indicate the outcome of this test.

_____

_____

(2 marks)

(c) What tests would you carry out to identify each of the **negative** ions in each of the unknown samples?

(8 marks)
(Total: 16 marks)

18. (a) Alternate carbon-carbon single and double bonds, measuring 147 pm and 133 pm respectively, make up 1,3,5-cyclohexatriene. Had benzene actually exhibited such bond lengths, the structure would not have exhibited a stable delocalised structure. Describe the structure of benzene.

(4 marks)

(b) (i) The enthalpy of hydrogenation (ΔH°_{hyd}) of 1,3,5-cyclohexatriene is -360 KJ mol^{-1}, whilst that of benzene is -208 KJ mol^{-1}. Explain briefly.

(2 marks)

(ii) Estimate the enthalpy change for the hydrogenation of cyclohexene.

_____

_____

_____

(2 marks)

(c) Indicate the reagents/conditions required and the main *monosubstitution* product in each of the following reactions.

(i) Nitration of benzene: _____

_____

_____

_____

(4 marks)

(ii) Sulfonation of benzene: _____

_____

_____

_____

(4 marks)

(Total: 16 marks)

19. (a) Consider the equation for the ionisation of hydrochloric acid:

$$HCl\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + Cl^-\ (aq)$$

(i) Define the terms acid and base, by referring to the ionisation of hydrochloric acid.

Acid: _____

_____

Base: _____

_____

(2 marks)

(ii) Define the terms conjugate acid and conjugate base, by referring to the ionisation of hydrochloric acid. Explain your reasoning.

Conjugate acid: _____

_____

Conjugate base: _____

_____

(2 marks)

(b) (i) Define the term *pH*.

_____

_____

_____

(2 marks)

(ii) Given that the concentration of hydrochloric acid is 0.01 mol dm^{-3}, what is its pH?

_____

_____

_____

_____

(3 marks)

(iii) Explain why the pH of 0.1M hydrochloric acid is 1, but that of 0.1M ethanoic acid is approximately 3.

_____

_____

_____

_____

(4 marks)

(iv) What is the maximum possible pH value? Explain your answer briefly.

_____

_____

_____

_____

(3 marks)

(Total: 16 marks)

20. (a) Give the electron configuration of an iodine atom.

_____

(2 marks)

(b) What are the highest and lowest oxidation states of iodine?

_____

(2 marks)

(c) Explain the relative oxidising power of the elements in group VII.

_____

_____

_____

_____

_____

_____

_____

_____

(6 marks)

(d) To distinguish between halide ions, test tube reactions are carried out using silver nitrate solution, followed by excess ammonia solution. Complete the following table.

Halide ion	Reaction with silver nitrate solution	Addition of excess ammonia solution
	A white precipitate is produced.	
Iodide (I^-)		
		The precipitate is insoluble in dilute ammonia solution.

(6 marks)

(Total: 16 marks)

Section C
Answer TWO questions from this Section

21. A solution of 0.2 mol dm^{-3} sulfuric acid was titrated against a sodium hydroxide solution of unknown concentration. The sulfuric acid solution was placed in the burette while the sodium hydroxide solution was placed in the conical flask.

(a) Write the procedure, in point form, that has to be followed in order to find the concentration of the sodium hydroxide solution. Highlight the washing procedures for each of the pieces of glassware that have to be carried out. (10 marks)

(b) A ***few drops*** of **indicator** are used for the titration. Explain the term '**indicator**'. Explain briefly why only a few drops of indicator are used. (5 marks)

(c) Three titrations were carried out. The values that are obtained, against 25.0cm^3 of sodium hydroxide solution, are given in the table below:

	Titration 1	**Titration 2**	**Titration 3**
Final burette reading (cm^3)	22.9	25.9	48.4
Initial burette reading (cm^3)	0.0	3.4	25.9

(i) Work out the titre value for each of the three titrations. (3 marks)

(ii) At least two **concordant titre values** are needed. Explain briefly what is meant by the term '**concordant titre values**'. (2 marks)

(iii) Write down the chemical equation of this acid-base reaction taking place, including state symbols. (3 marks)

(iv) Give also the ionic equation for this reaction. (2 marks)

(v) Calculate the average titre value to be used for the calculation of the concentration of the sodium hydroxide solution. Explain your reasoning. (4 marks)

(vi) Find the number of moles of sulfuric acid involved. (2 marks)

(vii) Calculate the number of moles of sodium hydroxide that react with it. (3 marks)

(viii) Calculate the concentration, in mol dm^{-3}, of the sodium hydroxide solution. Give your answer to **two places of decimal**. (6 marks)

(Total: 40 marks)

22. (a) "*The species Mn^{2+}, MnO_2, MnO_4^{2-} and MnO_4^-; Fe^{2+} and Fe^{3+}; and Cu^+ and Cu^{2+} show colour and variable oxidation states. MnO_2, Fe and Ni have catalytic properties.*"
Explain the above statement. (15 marks)

(b) Mn, Fe and Cu are transition metals. Explain briefly by showing the electronic configuration in *spd* notation. (5 marks)

(c) "*There is metal-ligand bonding in coordination compounds, which can be described in terms of an electrostatic model or dative covalent bonding.*"
Explain the terms 'ligand', 'coordination compounds', and 'dative covalent bonding'. (6 marks)

(d) Some examples of complex ions are: $[Fe(H_2O)_6]^{2+}$, $[CuCl_4]^{2-}$, $[Cu(NH_3)_4]^{2+}$, and $[Fe(CN)_6]^{3-}$.
Explain the term 'complex ions'.
For **each** of the five ions, conclude the shape. Show clearly the reasoning to arrive at the conclusion. (14 marks)

(Total: 40 marks)

23. (a) A sample of 5.44 g of hydrogen peroxide was placed in a sealed 250 cm^3 container at a temperature of 500 K.
    (i) Write down the reaction, including state symbols, for the decomposition of hydrogen peroxide to give water and oxygen. (3 marks)
    (ii) Calculate the number of moles of hydrogen peroxide present. (3 marks)
    (iii) Assuming complete reaction and that all the hydrogen peroxide decomposes, calculate the number of moles of oxygen produced. (2 marks)
    (iv) Calculate the mass of water, in grammes, produced. (3 marks)
    (v) Considering that the density of water is 1 g/cm^3, calculate the volume of water produced. (2 marks)
    (vi) Hence, calculate the volume of oxygen gas in m^3. (3 marks)
    (vii) Calculate the pressure of the oxygen gas in Pa. (4 marks)

    (b) Gases **X** and **Y** react together to form **Z**. The initial volumes of **Y** and **X** are 10 cm^3 and 3 cm^3 respectively, while there is no **Z** present in the gaseous mixture originally. The equation for this reaction is: $3X\ (g) + Y\ (g) \rightarrow 2Z\ (g)$
    (i) Assuming complete reaction, calculate the total volume of gas after reaction. Show clearly your reasoning. (4 marks)
    (ii) Indicate the two assumptions that are considered (apart from complete reaction) to work out part (i). (2 marks)

    (c) (i) If gases **X** and **Y** were hydrogen and nitrogen respectively, explain briefly what is observed if an open reagent bottle containing concentrated hydrochloric acid were placed near the mouth of the test tube where the reaction takes place. (3 marks)
    (ii) Write the equation of the reaction that takes place in part (c)(i). Include state symbols. (3 marks)
    (iii) This reaction between hydrogen and nitrogen is in actual fact a reversible reaction. Explain briefly what is meant by the term 'reversible reaction'. (2 marks)
    (iv) It is said that when equilibrium is reached, it is a dynamic equilibrium. Explain briefly what is meant by the term 'dynamic equilibrium'. (3 marks)
    (v) What happens if an inert gas is added to the system at equilibrium while maintaining a constant pressure? Explain briefly. (3 marks)

(Total: 40 marks)

24. (a) Consider the following redox reaction: $Cu\ (s) + 2AgNO_3\ (aq) \rightarrow Cu(NO_3)_2\ (aq) + 2Ag\ (s)$
    (i) Write the ionic equation for the above reaction. (2 marks)
    (ii) What are the 'parts' that are left out in the ionic equation with respect to the full equation called? (1 mark)
    (iii) Using oxidation numbers, indicate what is being oxidized and what is being reduced. (4 marks)
    (iv) Write the two half equations for this redox reaction. (2 marks)

    (b) Consider the following reaction:

$$3Cl_2\ (g) + 6NaOH\ (aq) \rightarrow 5NaCl\ (aq) + NaClO_3\ (aq) + 3H_2O\ (l)$$

    (i) Using oxidation numbers, indicate what is being oxidized and what is being reduced. (8 marks)
    (ii) Write the ionic equation for the above reaction. (4 marks)
    (iii) Write the two half equations for this redox reaction. (4 marks)
    (iv) What is this type of redox reaction called? Explain briefly your answer in terms of the above example. (3 marks)

(c) Consider this dictionary definition: "*Electrochemical series: Definitions, noun (chemistry) a series of the metals, together with hydrogen, arranged in the order of their electrode potentials*" http://www.collinsdictionary.com/dictionary/english/electrochemical-series

(i) Explain briefly the term 'electrochemical series' and indicate 'how it works'. Illustrate your answer with suitable examples. (8 marks)

(ii) A piece of magnesium is stuck to (and so is in contact with) a piece of iron. They are in conditions where they can corrode. Explain briefly which of the metals corrodes. (4 marks)

(Total: 40 marks)

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PERIODIC TABLE

I	II											III	IV	V	VI	VII	VIII
																	4 **He** 2
7 **Li** 3	9 **Be** 4											11 **B** 5	12 **C** 6	14 **N** 7	16 **O** 8	19 **F** 9	20 **Ne** 10
23 **Na** 11	24 **Mg** 12											27 **Al** 13	28 **Si** 14	31 **P** 15	32 **S** 16	35.5 **Cl** 17	40 **Ar** 18
39 **K** 19	40 **Ca** 20	45 **Sc** 21	48 **Ti** 22	51 **V** 23	52 **Cr** 24	55 **Mn** 25	56 **Fe** 26	59 **Co** 27	59 **Ni** 28	63.5 **Cu** 29	65 **Zn** 30	70 **Ga** 31	73 **Ge** 32	75 **As** 33	79 **Se** 34	80 **Br** 35	84 **Kr** 36
85 **Rb** 37	88 **Sr** 38	89 **Y** 39	91 **Zr** 40	93 **Nb** 41	96 **Mo** 42	99 **Tc** 43	101 **Ru** 44	103 **Rh** 45	106 **Pd** 46	108 **Ag** 47	112 **Cd** 48	115 **In** 49	119 **Sn** 50	122 **Sb** 51	128 **Te** 52	127 **I** 53	131 **Xe** 54
133 **Cs** 55	137 **Ba** 56	139 **La** 57	178.5 **Hf** 72	181 **Ta** 73	184 **W** 74	186 **Re** 75	190 **Os** 76	192 **Ir** 77	195 **Pt** 78	197 **Au** 79	201 **Hg** 80	204 **Tl** 81	207 **Pb** 82	209 **Bi** 83	209 **Po** 84	210 **At** 85	222 **Rn** 86
223 **Fr** 87	226 **Ra** 88	227 **Ac** 89															

Key

Relative atomic mass — A, X, Z — *Atomic Number*

140 **Ce** 58	141 **Pr** 59	144 **Nd** 60	147 **Pm** 61	150 **Sm** 62	152 **Eu** 63	157 **Gd** 64	159 **Tb** 65	162 **Dy** 66	165 **Ho** 67	167 **Er** 68	169 **Tm** 69	173 **Yb** 70	175 **Lu** 71
232 **Th** 90	231 **Pa** 91	238 **U** 92	237 **Np** 93	244 **Pu** 94	243 **Am** 95	247 **Cm** 96	247 **Bk** 97	251 **Cf** 98	252 **Es** 99	257 **Fm** 100	258 **Md** 101	259 **No** 102	260 **Lr** 103