

Cambridge International AS & A Level

CHEMISTRY

Paper 1 Multiple Choice

9701/11 May/June 2022 1 hour 15 minutes

You must answer on the multiple choice answer sheet.

You will need: Multiple choice answer sheet Soft clean eraser Soft pencil (type B or HB is recommended)

INSTRUCTIONS

- There are forty questions on this paper. Answer all questions.
- For each question there are four possible answers **A**, **B**, **C** and **D**. Choose the **one** you consider correct and record your choice in soft pencil on the multiple choice answer sheet.
- Follow the instructions on the multiple choice answer sheet.
- Write in soft pencil.
- Write your name, centre number and candidate number on the multiple choice answer sheet in the spaces provided unless this has been done for you.
- Do **not** use correction fluid.
- Do not write on any bar codes.
- You may use a calculator.

INFORMATION

- The total mark for this paper is 40.
- Each correct answer will score one mark.
- Any rough working should be done on this question paper.
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

1 Which atom has its outermost electron in an orbital of the shape shown, with principal quantum number 3?



- A sodium
- **B** chlorine
- **C** calcium
- **D** bromine
- 2 Which atom has the same number of electrons as the hydroxide ion, OH⁻?

Α	F	В	Ne	С	Na	D	Mg
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3 In separate experiments, 5.0 g samples of each of four s-block metals are added to an excess of water. The gas evolved is collected and its volume measured under the same conditions of temperature and pressure for each sample.

Which metal produces the largest volume of gas?

- A calcium
- **B** potassium
- **C** rubidium
- **D** strontium
- **4** A student reacts 1 mol of copper with concentrated nitric acid to produce 1 mol of copper(II) nitrate, 2 mol of water and substance X. No other product is formed.

Substance X does not contain copper or hydrogen.

What could be substance X?

- 5 In which structure are three atoms bonded together in a straight line?
 - **A** poly(ethene), $-(CH_2CH_2)_n$
 - B propane, C₃H₈
 - **C** silicon tetrachloride, SiC l_4
 - **D** sulfur hexafluoride, SF₆

- 6 Which statement about aluminium chloride is correct?
 - A Aluminium chloride has a much higher melting point than magnesium chloride due to the small size of the aluminium ion.
 - **B** Anhydrous aluminium chloride reacts vigorously with water to form a solution with a pH greater than 7.
 - **C** Each Al_2Cl_6 molecule found in aluminium chloride vapour contains two coordinate bonds.
 - **D** The bonding between aluminium and chlorine is strongly ionic due to the large difference in electronegativity.
- 7 'Black powder' is a mixture of potassium nitrate, carbon and sulfur. The mixture reacts as shown.

 $4 \mathsf{KNO}_3(s) \ + \ 7 \mathsf{C}(s) \ + \ \mathsf{S}(s) \ \to \ 3 \mathsf{CO}_2(g) \ + \ 3 \mathsf{CO}(g) \ + \ 2 \mathsf{N}_2(g) \ + \ \mathsf{K}_2 \mathsf{S}(s) \ + \ \mathsf{K}_2 \mathsf{CO}_3(s)$

A sealed tube containing black powder has a volume of 10.0 cm^3 . When all of the black powder reacts, the reaction causes a pressure of $2 \times 10^6 \text{ Pa}$ and a temperature of 2500 K.

The volume of the K_2CO_3 and K_2S produced can be ignored.

How many moles of KNO_3 are contained in the sealed tube?

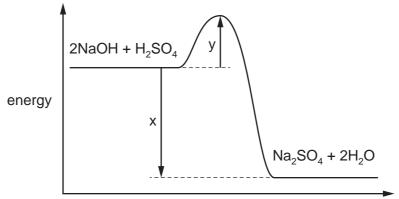
- $\label{eq:alpha} \begin{array}{ccc} \textbf{A} & 4.81 \times 10^{-4} & \textbf{B} & 9.63 \times 10^{-4} & \textbf{C} & 1.93 \times 10^{-3} & \textbf{D} & 9.63 \times 10^{-1} \end{array}$
- 8 For which pair is the boiling point of the first compound **higher** than the boiling point of the second compound?
 - **A** CH_3CH_2OH and CH_3CH_2SH
 - **B** $CH_3CO_2CH_3$ and $CH_3CH_2CO_2H$
 - $\textbf{C} \quad CH_{3}OCH_{3} \text{ and } CH_{3}CH_{2}OH$
 - $\textbf{D} \quad CH_3CH_2CHO \ and \ CH_3CH_2CO_2H$
- **9** The equation for an enthalpy change is shown. The enthalpy change is Q.

 $2C(s) + 3H_2(g) + 3.5O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(I)$

What is the correct expression to calculate Q?

- $\label{eq:A} \textbf{A} \quad 2 \times \Delta \boldsymbol{H}^{e}_{c}\left[CO_{2}(g)\right] \ \ 3 \times \Delta \boldsymbol{H}^{e}_{f}\left[\boldsymbol{H}_{2}(g)\right]$
- $\label{eq:bound} \begin{array}{ll} \textbf{B} & 3 \times \Delta \boldsymbol{H}_{\,f}^{\,e}\left[\boldsymbol{H}_{2}\boldsymbol{O}(g)\right] \ \textbf{+} \ 2 \times \Delta \boldsymbol{H}_{\,c}^{\,e}\left[\boldsymbol{C}\boldsymbol{O}_{2}(g)\right] \end{array}$
- $\label{eq:constraint} \begin{array}{ll} \textbf{C} & 2 \times \Delta \boldsymbol{H}_{\,f}^{\,e}\left[CO_{2}(g)\right] \, \, 3 \times \Delta \boldsymbol{H}_{\,f}^{\,e}\left[\boldsymbol{H}_{2}(g)\right] \end{array}$
- $\label{eq:def_def_def} \begin{array}{ll} \textbf{D} & 3 \times \Delta \boldsymbol{H}_{\,f}^{e}\left[H_{2}O(l)\right] \ \textbf{+} \ 2 \times \Delta \boldsymbol{H}_{\,f}^{e}\left[CO_{2}(g)\right] \end{array}$

10 A reaction pathway diagram for the reaction of aqueous sodium hydroxide and dilute sulfuric acid is shown.



progress of reaction

What is the value of the enthalpy change of neutralisation, ΔH_{neut} ?

Α	x	в	x – y	С	<u>x</u> 2	D	$\frac{(x-y)}{2}$
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11 A student reacts 4 mol of ammonia with oxygen to produce an oxide of nitrogen and water only. Each nitrogen atom increases its oxidation state by 5 in the reaction.

How many moles of oxygen gas react with 4 mol of ammonia in this reaction?

Α	4 mol	В	5 mol	С	7 mol	D	10 mol
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12 In the treatment of domestic water supplies, chlorine is added to water to kill bacteria. Some ClO^{-} ions are formed.

What is the change in oxidation number of chlorine when forming the ClO^{-} ion from aqueous chlorine?

A -1 B 0 C +1 D +2

13 Ethanoic acid is mixed with ethanol.

The ethanol is contaminated with a small amount of methanol.

The following equilibria are established.

$$CH_{3}CO_{2}H(I) + CH_{3}CH_{2}OH(I) \rightleftharpoons CH_{3}CO_{2}CH_{2}CH_{3}(I) + H_{2}O(I) \qquad K_{c} = K_{1}$$
$$CH_{3}CO_{2}H(I) + CH_{3}OH(I) \rightleftharpoons CH_{3}CO_{2}CH_{3}(I) + H_{2}O(I) \qquad K_{c} = K_{2}$$

Which statement about the equilibrium mixture is correct?

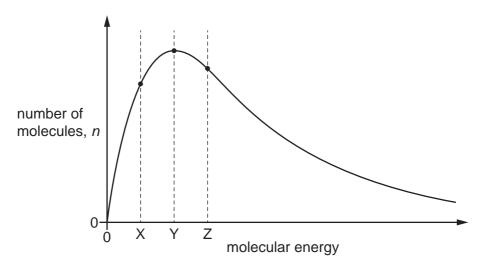
- A Only ethyl ethanoate will be formed because there is much more ethanol present than methanol.
- **B** In this mixture $\frac{[CH_3CO_2CH_2CH_3]}{[CH_3CO_2CH_3]} = \frac{K_1}{K_2}.$
- **C** Adding water to the mixture will alter the mole ratio of the two esters.
- **D** Adding methyl ethanoate to the mixture will increase the number of moles of ethyl ethanoate.
- **14** SO_3 is manufactured from SO_2 and O_2 in the Contact process.

The reaction is exothermic.

Which row shows the effect on the equilibrium yield obtained in the Contact process of increasing the temperature and of adding a vanadium(V) oxide catalyst?

	increasing the temperature	adding vanadium(V) oxide as catalyst
Α	equilibrium yield decreases	equilibrium yield increases
в	equilibrium yield decreases	equilibrium yield unchanged
С	equilibrium yield increases	equilibrium yield unchanged
D	equilibrium yield increases	equilibrium yield increases

15 The Boltzmann distribution for a gas at a constant temperature of 50 °C is shown.



If the temperature of the gas is **reduced** by $10 \,^{\circ}$ C, the graph changes shape.

	Х	Y	Z
Α	higher	lower	higher
в	higher	lower	lower
С	lower	higher	lower
D	lower	lower	lower

What happens to the values of n for the molecular energies X, Y and Z?

16 A 3.0 g sample of Na₂CO₃ powder is stirred into 50 cm^3 of $1.0 \text{ mol dm}^{-3} \text{ HC}l$. The volume of CO₂ produced is 600 cm^3 .

 $Na_2CO_3(s)$ + 2HC $l(aq) \rightarrow 2NaCl(aq)$ + $CO_2(g)$ + $H_2O(I)$

[*M*_r: Na₂CO₃, 106.0]

Which volume of CO_2 is produced if 1.0 g of Na_2CO_3 powder is stirred into 50 cm^3 of $1.0 \text{ mol dm}^{-3} \text{ HC}l$ under the same conditions?

A 600 cm^3 **B** 452 cm^3 **C** 226 cm^3 **D** 200 cm^3

17 Solid sodium iodide reacts with concentrated sulfuric acid to form more than one product that contains sulfur.

What is the lowest oxidation number of sulfur in these products?

A -2 **B** 0 **C** +4 **D** +6

- **18** Which statement for the element in Period 3 and Group 13 of the Periodic Table is correct?
 - **A** It has the highest melting point of the elements in its period.
 - **B** It has exactly one electron in its shell with principal quantum number 3.
 - **C** It forms an oxide that reacts with aqueous sodium hydroxide.
 - **D** It forms a chloride that dissolves in water to give a neutral solution.
- **19** A student reacts 0.100 mol of each of sodium, magnesium and phosphorus atoms separately with an excess of oxygen.

Which rows are correct?

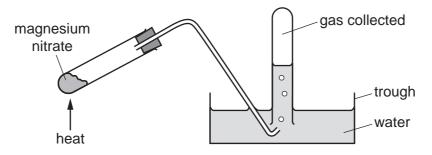
	oxide	mass of oxide formed/g
1	sodium	3.10
2	magnesium	4.03
3	phosphorus	7.10

- **A** 1, 2 and 3 **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only
- **20** A mixture contains magnesium carbonate and barium carbonate only. A sample of the mixture is dissolved in nitric acid to produce a solution.

How could this solution be processed into a magnesium compound and a separate barium compound?

- **A** Add HCl(aq), filter off the solid barium chloride.
- **B** Add HCl(aq), filter off the solid magnesium chloride.
- **C** Add $H_2SO_4(aq)$, filter off the solid barium sulfate.
- **D** Add $H_2SO_4(aq)$, filter off the solid magnesium sulfate.

21 A sample of magnesium nitrate is heated in the apparatus shown.



The pH of the solution in the trough is measured.

The gas collected is tested with a glowing splint.

What are the results?

	pH of solution in trough	splint test
Α	8	relights
в	2	relights
С	8	extinguished
D	2	extinguished

22 The results of tests performed on a white crystalline solid, X, are given in the table.

reagent and conditions	observation
X is gently heated	X sublimes
X is shaken with H_2O	a colourless solution, Y, forms
Y is warmed with NaOH(aq)	a gas is given off
AgNO ₃ (aq) is added to Y	a white precipitate, Z, forms
Z is shaken with NH ₃ (aq)	a colourless solution forms

What is the identity of X?

- A aluminium bromide
- B aluminium chloride
- **C** ammonium bromide
- D ammonium chloride

An excess of water is added to the sample of J produced.

Which row is correct?

	structure of J	Is HC <i>l</i> produced when water is added to J?
Α	giant molecular	no
в	giant molecular	yes
С	simple molecular	no
D	simple molecular	yes

24 In a catalytic converter, 5.6 g of carbon monoxide react with an excess of nitrogen monoxide.

What is produced in this reaction?

- **A** 2.4 g of C and 6.0 g of NO_2
- $\textbf{B} \quad 2.4\,g \text{ of C and } 9.2\,g \text{ of } NO_2$
- $\label{eq:constraint} \textbf{D} \quad 8.8\,g \text{ of } CO_2 \text{ and } 2.8\,g \text{ of } N_2$
- 25 Which reaction mixture produces an acidic gas?
 - A aqueous ammonium nitrate and solid calcium oxide
 - B calcium and aqueous hydrochloric acid
 - **C** potassium chloride and concentrated sulfuric acid
 - D sodium oxide and water

26 Ethanol can be used to make propanenitrile in two steps.

$$\begin{array}{cccc} X & Y \\ CH_3CH_2OH & \longrightarrow & CH_3CH_2Br & \longrightarrow & CH_3CH_2CN \end{array}$$

What types of reaction are X and Y?

	Х	Y
Α	free-radical substitution	electrophilic substitution
в	free-radical substitution	nucleophilic substitution
С	nucleophilic substitution	nucleophilic substitution
D	nucleophilic substitution	electrophilic substitution

- **27** Which compound will react with $LiAlH_4$ to form two optical isomers?
 - A CH₃CH₂COCH₃
 - B CH₃CH₂CH₂CHO
 - C CH₃CH₂COCH₂CH₃
 - $\textbf{D} \quad CH_3CH(CH_3)CH_2CO_2H$
- **28** How many esters have the molecular formula $C_4H_8O_2$?

Α	2	B 3	C 4	D	5

29 Carbon monoxide, CO, nitrogen dioxide, NO₂, and sulfur dioxide, SO₂, are all atmospheric pollutants.

Which reaction occurs in the atmosphere?

- **A** CO is spontaneously oxidised to CO₂.
- $\label{eq:bound} \textbf{B} \quad NO_2 \text{ is reduced to } NO \text{ by } SO_2.$
- $\label{eq:constraint} \begin{tabular}{cc} NO_2 is reduced to NO by CO. \end{tabular}$

30 Oct-1-ene, $CH_3(CH_2)_5CH=CH_2$, can be thermally cracked.

Which of the compounds W, X, Y and Z can be obtained by thermally cracking oct-1-ene?

W	Х	Y	Z	
CH ₂ =CH	L ₂ CH ₃ CH=C	CH ₂ CH ₃ CH ₂	CH ₃ CH ₂ =CHCI	H=CH ₂
W, X, Y and Z				
W, X and Y only	у			
W, X and Z only	y			
W and X only				

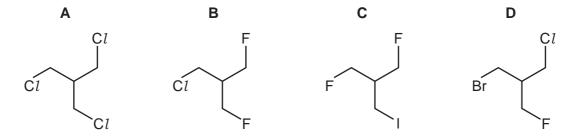
31 Structural isomerism and stereoisomerism should be taken into account when answering this question.

How many isomeric alkenes with formula C_5H_8 are present in the mixture produced when 1,4-dibromopentane is reacted with NaOH in ethanol?

A 1 **B** 2 **C** 3 **D** 4

32 The presence of a halogen in an organic compound may be detected by warming the organic compound with aqueous silver nitrate.

Which compound would be the quickest to produce a precipitate?



33 17.6 g of pentan-1-ol is completely combusted.

Which volume of gaseous products is formed when measured at s.t.p.?

A 22.4 dm³ **B** 24.0 dm³ **C** 49.3 dm³ **D** 52.8 dm³

Α

В

С

D

34 Crotyl alcohol, $CH_3CH=CHCH_2OH$, is a colourless liquid which is used as a solvent.

Crotyl alcohol will react separately with Br_2 , $K_2Cr_2O_7/H^+$, conc. $KMnO_4/H^+$ and PCl_5 under suitable conditions.

Which row is correct?

	reactant	conditions	main product
Α	Br ₂	room temperature	CH ₃ CH=CHCH ₂ Br
В	$K_2Cr_2O_7/H^+$	heat under reflux	CH₃CH=CHCHO
С	conc. KMnO₄/H⁺	heat under reflux	CH ₃ CH=CHCO ₂ H
D	PC15	room temperature	CH ₃ CH=CHCH ₂ Cl

35 The skeletal formulae of two organic compounds are shown.



Which reagents can be used to distinguish these two compounds?

- 1 alkaline I₂(aq)
- 2 acidified K₂Cr₂O₇
- 3 2,4-dinitrophenylhydrazine (2,4-DNPH reagent)
- **A** 1, 2 and 3 **B** 1 and 3 only **C** 2 and 3 only **D** 2 only
- **36** A carbonyl compound, X, reacts with HCN in the presence of NaCN to make a compound with M_r 85. Compound X does **not** react with Fehling's reagent.

What is compound X?

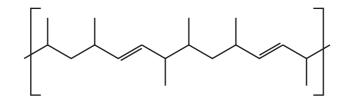
- A butanal
- B butanone
- **C** propanal
- D propanone

- 37 Which compound produces butan-2-ol and ethanoic acid on hydrolysis?
 - **A** $CH_3CO_2CH(CH_3)_2$
 - $\textbf{B} \quad CH_3CO_2CH(CH_3)CH_2CH_3$
 - $\textbf{C} \quad CH_3CH(CH_3)CO_2CH_2CH_3$
 - $\mathbf{D} \quad CH_3CH_2CO_2CH(CH_3)CH_2CH_3$
- **38** Two 1 g samples of Y are reacted separately and completely with sodium and with sodium carbonate. The volumes of the gases produced are collected and measured.

	relative volur	nes of gases
	with Na	with Na ₂ CO ₃
Υ	2	1

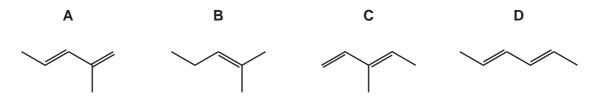
What could Y be?

- A CH₃CH(OH)CH₂OH
- B CH₃CH(OH)CO₂H
- C CH₃COCH₂OH
- **D** CH₃COCO₂H
- **39** The diagram shows a section of an addition polymer formed from two different monomers.



One of the monomers is propene.

What is the other monomer?



40 A scientist chooses either infrared spectroscopy or mass spectrometry to find a particular piece of information.

In which row has the **best** choice been made?

	target information	analytic method used
Α	identities of functional groups in an organic compound	infrared spectroscopy
в	identities of functional groups in an organic compound	mass spectrometry
С	values of successive ionisation energies of Na	infrared spectroscopy
D	values of successive ionisation energies of Na	mass spectrometry

molar gas constant	$R = 8.31 \mathrm{J}\mathrm{K}^{-1}\mathrm{mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \mathrm{C}\mathrm{mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23} \mathrm{mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \mathrm{C}$
molar volume of gas	$V_{\rm m}$ = 22.4 dm ³ mol ⁻¹ at s.t.p. (101 kPa and 273 K) $V_{\rm m}$ = 24.0 dm ³ mol ⁻¹ at room conditions
ionic product of water	$K_{\rm w}$ = 1.00 × 10 ⁻¹⁴ mol ² dm ⁻⁶ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \mathrm{kJ} \mathrm{kg}^{-1} \mathrm{K}^{-1} (4.18 \mathrm{J} \mathrm{g}^{-1} \mathrm{K}^{-1})$

Important values, constants and standards

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109 110 111 112 113 114 115 116 117 Mt Ds Rg Cn Nh F1 Mc Lv T5 116 117 mettretum damstadbum coententum inhonum ferovium mescorium twemorum tennosium	hafnium tantalum tungsten rhenium 178.5 180.9 183.8 186.2	tantalum tungsten rhenium 180.9 183.8 186.2	tantalum tungsten rhenium 180.9 183.8 186.2	tungsten rhenium 183.8 186.2	rhenium 186.2		osmiu 190.	ΕN	iridium 192.2	platinum 195.1	gold 197.0	mercury 200.6	thallium 204.4	lead 207.2	bismuth 209.0	polonium –	astatine -	radon -
Mt Ds Rg Cn Nh F1 Mc Lv Ts mettneruum damstadbum coentgenum opericium nihonium ferovium metorium terovium <	105 106 107	104 105 106 107	105 106 107	106 107	107		108	_	109	110	111	112	113	114	115	116	117	118
metitrerium darmstadium roenigenium copernicium nihonium flerovium moscovium livermorium tennessine	Db Sg	Rf Db Sg Bh	Db Sg Bh	Sg Bh	Bh		Ï	~	Mt	Ds	Rg	C	ЧN	Fl	Mc	2	Чs	0g
	rutherfordium dubnium seaborgium bohrium t 	dubnium seaborgium bohrium	dubnium seaborgium bohrium	seaborgium bohrium -	bohrium I		hassiu –	E	meitnerium -	darmstadtium -	roentgen ium -	copernicium -	nihonium –	flerovium -	moscovium -	livermorium -	tennessine -	oganesson -
	57 58 59 60 61 62	58 59 60 61	59 60 61	60 61	61		62		63	64	65	66		68	69	70	71	
64 65 66 67 68 69 70	Ce Pr Nd Pm	Ce Pr Nd Pm	Pr Nd Pm	Nd	Pm		Sn	_	Eu	Вd	Tb	D		ц	Tm	γb	Lu	
63 64 65 66 67 68 69 70 Eu Gd Tb Dy Ho Er Tm Yb	lanthanum cerium praseodymium neodymium pr 138.9 140.1 140.9 144.4	cerium praseodymium neodymium promethium 140.1 140.9 144.4 –	praseodymium neodymium promethium 140.9 144.4 –	neodymium promethium 144.4 –	neodymium promethium 144.4 –		sama 150	nium 1.4	europium 152.0	gadolinium 157.3	terbium 158.9	dysprosium 162.5		erbium 167.3	thulium 168.9	ytterbium 173.1	lutetium 175.0	
63 64 65 66 67 68 69 70 Eu Gd Tb Dy HO Er Tm Yb europium gadolium tetbium dysprosium homium etbium tetbium ytetbium 152.0 157.3 158.9 162.5 164.9 157.3 178.10	90 91 92 93	90 91 92 93	91 92 93	92 93	93			94	95	96	97	98		100	101	102	103	
63 64 65 66 67 68 69 70 Eu Gd Tb Dy HO Er Tm Yb europium gadolinum tetium dysprosium holmium f87.3 188.9 173.1 152.0 157.3 158.9 162.5 96 97 100 101 102	actinoids Ac Th Pa U Np Pu	Th Pa U Np	Pa U Np	N			٩	n	Am	CB	剐	ç	Es	Еm	Md	No	Ļ	
63 64 65 66 67 68 69 70 Eu Gd Tb Dy Ho Er Tm Yb europium gadolinum terbium dysprosium homium eibium ytartium 152.0 157.3 158.9 162.5 164.9 167.3 168.9 173.1 95 96 97 98 99 100 101 102 Am Cm Bk Cf Es Fm Md No	thorium protactinium uranium neptunium	thorium protactinium uranium neptunium	protactinium uranium neptunium 231.0 238.0 _	uranium neptunium	neptunium		plutoni	Ę	americium	curium	berkelium _	californium _	einsteinium 	fermium _	mendelevium 	nobelium _	lawrencium 	

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ytterbium 173.1 102 No nobelium 168.9 101 Md mendelev erbium 167.3 100 **FM** fermium 99 ES einsteinium holmium 164.9 dysprosium 162.5 98 Cf californium 158.9 97 **BK** berkelium gadolinium 157.3 ⁹⁶ O ⁹⁶ europium 152.0 95 Am americium 150.4 94 PU promethium 93 Np neptunium neodymiu. 144.4 92 U uranium 238.0 91 Pa protactinium 231.0 140.9 cerium 140.1 90 232.0 lanthanum 138.9 89 **AC** actinium actinoids

The Periodic Table of Elements

PMT