INTERNATIONAL UNION OF
PURE AND APPLIED CHEMISTRY

INORGANIC CHEMISTRY DIVISION
COMMISSION ON ATOMIC WEIGHTS

ATOMIC WEIGHTS OF THE ELEMENTS 1973

LONDON

BUTTERWORTHS

INORGANIC CHEMISTRY DIVISION

COMMISSION ON ATOMIC WEIGHTS*

ATOMIC WEIGHTS OF THE ELEMENTS

CHANGES IN ATOMIC WEIGHT VALUES

On the basis of work published, accepted for publication, or re-evaluated from earlier publications the Commission recommends only two changes in atomic weights: namely, for nickel 58.70 (instead of the former value of 58.7_1)[1] and for rhenium 186.207 (instead of the former value of 186.2). The change for nickel is well within the formerly implied uncertainty of 0.03 and that uncertainty has been decreased by a factor of three. The new value for rhenium is consistent with the former less precise value but the uncertainty has been reduced by a factor of 100, a rare event in the history of atomic weight determinations. These changes in value were given to the technical press in a news release immediately following the XXVII IUPAC Conference held in Munich, Germany, August 1973. The reasons for the two changes are set out below.

Nickel is an important and abundant element in nature but its atomic weight is among the least precisely known for reasons other than excessive variability in 'normal' materials. The best chemical determinations of $A_r(Ni)$ are in a series of papers by Baxter using the Harvard titrimetric method. Baxter and Parsons[2] analyzed nickel(II) oxide and obtained Ni/O = 3.66887 for six determinations of terrestrial nickel. This gave $A_r(Ni)$ = 58.700 (this and all other values here quoted were recalculated to conform to the scale $A_r(^{12}C) = 12$ exactly). Baxter and Hilton[3] analyzed nickel(II) chloride and obtained $NiCl_2/2Ag = 0.6007$ for six determinations and $NiCl_2/2AgCl$ = 0.452118 for two determinations of terrestrial nickel. This gave $A_r(Ni)$ = 58.692. Baxter and Ishimaru[4] analyzed nickel(II) bromide and obtained $NiBr_2/2Ag = 1.012829$ for five determinations and $NiBr_2/2AgBr = 0.581817$ for three determinations of terrestrial nickel. This gave $A_r(Ni)$ = 58.695. A reasonable value from these results is $A_r(Ni) = 58.695 \pm 0.005$. When White and Cameron[5] published their mass spectrometric data, which gave $A_r(Ni)$ = 58.710 after recalculation to $A_r(^{12}C) = 12$, the Commission in 1955 preferred that value to the chemical one. However, the still unexplained discrepancy with the chemical value led the Commission in 1969 to admit the possibility of an error of 0.03 in that value thus amply encompassing both the physical and the chemical values. It now appears that White and Cameron may have

* *Titular Members*: N. N. Greenwood, Chairman (UK): H. S. Peiser, Secretary (USA): P. De Bièvre (Belgium): S. Fujiwara (Japan): N. E. Holden (USA): W. H. Johnson (USA): W. W. Meinke (USA): E. Roth (France): *Associate Members*: A. E. Cameron (USA): G. N. Flerov (USSR): R. L. Martin (Australia): N. Saito (Japan): H. G. Thode (Canada) and A. H. Wapstra (The Netherlands).

TABLE OF ATOMIC WEIGHTS 1973

Scaled to the relative atomic mass, $A_r(^{12}C) = 12$

The atomic weights of many elements are not invariant but depend on the origin and treatment of the material. The footnotes to this Table elaborate the types of variation to be expected for individual elements. The values of $A_r(E)$ given here apply to elements as they exist naturally on earth and to certain artificial elements. When used with due regard to the footnotes they are considered reliable to ± 1 in the last digit or ± 3 when followed by an asterisk*. Values in parentheses are used for certain radioactive elements whose atomic weights cannot be quoted precisely without knowledge of origin; the value given is the atomic mass number of the isotope of that element of longest known half life.

Alphabetical Order in English

Name	Symbol	Atomic number	Atomic weight	Footnotes
Actinium	Ac	89	(227)	
Aluminium	Al	13	26.98154	a
Americium	Am	95	(243)	
Antimony	Sb	51	121.75*	
Argon	Ar	18	39.948*	b, c, d, g
Arsenic	As	33	74.9216	a
Astatine	At	85	(210)	
Barium	Ba	56	137.34*	
Berkelium	Bk	97	(247)	
Beryllium	Be	4	9.01218	a
Bismuth	Bi	83	208.9804	a
Boron	B	5	10.81	c, d, e
Bromine	Br	35	79.904	c
Cadmium	Cd	48	112.40	
Caesium	Cs	55	132.9054	a
Calcium	Ca	20	40.08	g
Californium	Cf	98	(251)	
Carbon	C	6	12.011	b, d
Cerium	Ce	58	140.12	
Chlorine	Cl	17	35.453	c
Chromium	Cr	24	51.996	c
Cobalt	Co	27	58.9332	a
Copper	Cu	29	63.546*	c, d
Curium	Cm	96	(247)	
Dysprosium	Dy	66	162.50*	
Mercury	Hg	80	200.59*	
Molybdenum	Mo	42	95.94*	
Neodymium	Nd	60	144.24*	
Neon	Ne	10	20.179*	c, e
Neptunium	Np	93	237.0482	f
Nickel	Ni	28	58.70	
Niobium	Nb	41	92.9064	a
Nitrogen	N	7	14.0067	b, c
Nobelium	No	102	(255)	
Osmium	Os	76	190.2	g
Oxygen	O	8	15.9994*	b, c, d
Palladium	Pd	46	106.4	
Phosphorus	P	15	30.97376	a
Platinum	Pt	78	195.09*	
Plutonium	Pu	94	(244)	
Polonium	Po	84	(209)	
Potassium	K	19	39.098*	
Praseodymium	Pr	59	140.9077	a
Promethium	Pm	61	(145)	
Protactinium	Pa	91	231.0359	f
Radium	Ra	88	226.0254	f, g
Radon	Rn	86	(222)	
Rhenium	Re	75	186.207	c
Rhodium	Rh	45	102.9055	a
Rubidium	Rb	37	85.4678*	c

Einsteinium	Es	99	(254)	
Erbium	Er	68	167.26*	
Europium	Eu	63	151.96	
Fermium	Fm	100	(257)	
Fluorine	F	9	18.99840	a
Francium	Fr	87	(223)	
Gadolinium	Gd	64	157.25*	
Gallium	Ga	31	69.72	
Germanium	Ge	32	72.59*	
Gold	Au	79	196.9665	a
Hafnium	Hf	72	178.49*	
Helium	He	2	4.00260	b, c
Holmium	Ho	67	164.9304	a
Hydrogen	H	1	1.0079	b, d
Indium	In	49	114.82	
Iodine	I	53	126.9045	a
Iridium	Ir	77	192.22*	
Iron	Fe	26	55.847*	
Krypton	Kr	36	83.80	e
Lanthanum	La	57	138.9055*	b
Lawrencium	Lr	103	(260)	
Lead	Pb	82	207.2	d, g
Lithium	Li	3	6.941*	c, d, e, g
Lutetium	Lu	71	174.97	
Magnesium	Mg	12	24.305	c, g
Manganese	Mn	25	54.9380	a
Mendelevium	Md	101	(258)	

Ruthenium	Ru	44	101.07*	
Samarium	Sm	62	150.4	
Scandium	Sc	21	44.9559	a
Selenium	Se	34	78.96*	
Silicon	Si	14	28.086*	d
Silver	Ag	47	107.868	c
Sodium	Na	11	22.98977	a
Strontium	Sr	38	87.62	g
Sulfur	S	16	32.06	d
Tantalum	Ta	73	180.9479*	b
Technetium	Tc	43	(97)	
Tellurium	Te	52	127.60*	
Terbium	Tb	65	158.9254	a
Thallium	Tl	81	204.37*	
Thorium	Th	90	232.0381	f, g
Thulium	Tm	69	168.9342	a
Tin	Sn	50	118.69*	
Titanium	Ti	22	47.90*	
Tungsten (Wolfram)	W	74	183.85*	
Uranium	U	92	238.029	b, c, e, g
Vanadium	V	23	50.9414*	b, c
Xenon	Xe	54	131.30	e
Ytterbium	Yb	70	173.04*	
Yttrium	Y	39	88.9059	a
Zinc	Zn	30	65.38	
Zirconium	Zr	40	91.22	

[a] Element with only one stable nuclide.

[b] Element with one predominant isotope (about 99 to 100 per cent abundance); variations in the isotopic composition or errors in its determination have a correspondingly small effect on the value of A_r(E).

[c] Element for which the value of A_r(E) derives its reliability from calibrated measurements (i.e. from comparisons with synthetic mixtures of known isotopic composition).

[d] Element for which known variations in isotopic composition in terrestrial material prevent a more precise atomic weight being given; A_r(E) values should be applicable to any 'normal' material.

[e] Element for which substantial variations in A_r from the value given can occur in commercially available material because of inadvertent or undisclosed change of isotopic composition.

[f] Element for which the value of A_r is that of the most commonly available long-lived isotope.

[g] Element for which geological specimens are known in which the element has an anomalous isotopic composition.

TABLE OF ATOMIC WEIGHTS 1973

Scaled to the relative atomic mass. $A_r(^{12}C) = 12$

The atomic weights of many elements are not invariant but depend on the origin and treatment of the material. The footnotes to this Table elaborate the types of variation to be expected for individual elements. The values of $A_r(E)$ given here apply to elements as they exist naturally on earth and to certain artificial elements. When used with due regard to the footnotes they are considered reliable to ± 1 in the last digit or ± 3 when followed by an asterisk*. Values in parentheses are used for certain radioactive elements whose atomic weights cannot be quoted precisely without knowledge of origin: the value given is the atomic mass number of the isotope of that element of longest known half life.

Order of Atomic Number

Atomic number	Name	Symbol	Atomic weight	Footnotes	Atomic number	Name	Symbol	Atomic weight	Footnotes
1	Hydrogen	H	1.0079	b, d	53	Iodine	I	126.9045	a
2	Helium	He	4.00260	b, c	54	Xenon	Xe	131.30	e
3	Lithium	Li	6.941*	c, d, e, g	55	Caesium	Cs	132.9054	a
4	Beryllium	Be	9.01218	a	56	Barium	Ba	137.34*	
5	Boron	B	10.81	c, d, e	57	Lanthanum	La	138.9055*	b
6	Carbon	C	12.011	b, d	58	Cerium	Ce	140.12	
7	Nitrogen	N	14.0067	b, c	59	Praseodymium	Pr	140.9077	a
8	Oxygen	O	15.9994*	b, c, d	60	Neodymium	Nd	144.24*	
9	Fluorine	F	18.99840	a	61	Promethium	Pm	(145)	
10	Neon	Ne	20.179*	c, e	62	Samarium	Sm	150.4	
11	Sodium	Na	22.98977	a	63	Europium	Eu	151.96	
12	Magnesium	Mg	24.305	c, g	64	Gadolinium	Gd	157.25*	
13	Aluminium	Al	26.98154	a	65	Terbium	Tb	158.9254	a
14	Silicon	Si	28.086*	d	66	Dysprosium	Dy	162.50*	
15	Phosphorus	P	30.97376	a	67	Holmium	Ho	164.9304	a
16	Sulfur	S	32.06	d	68	Erbium	Er	167.26*	
17	Chlorine	Cl	35.453	c	69	Thulium	Tm	168.9342	a
18	Argon	Ar	39.948*	b, c, d, g	70	Ytterbium	Yb	173.04*	
19	Potassium	K	39.098*		71	Lutetium	Lu	174.97	
20	Calcium	Ca	40.08	g	72	Hafnium	Hf	178.49*	
21	Scandium	Sc	44.9559	a	73	Tantalum	Ta	180.9479*	b
22	Titanium	Ti	47.90*		74	Wolfram (Tungsten)	W	183.85*	
23	Vanadium	V	50.9414*	b, c	75	Rhenium	Re	186.207	c
24	Chromium	Cr	51.996	c	76	Osmium	Os	190.2	g

25	Manganese	Mn	54.9380	a	77	Iridium	Ir	192.22*	
26	Iron	Fe	55.847*		78	Platinum	Pt	195.09*	
27	Cobalt	Co	58.9332	a	79	Gold	Au	196.9665	a
28	Nickel	Ni	58.70		80	Mercury	Hg	200.59*	
29	Copper	Cu	63.546*	c, d	81	Thallium	Tl	204.37*	
30	Zinc	Zn	65.38		82	Lead	Pb	207.2	d, g
31	Gallium	Ga	69.72		83	Bismuth	Bi	208.9804	a
32	Germanium	Ge	72.59*		84	Polonium	Po	(209)	
33	Arsenic	As	74.9216	a	85	Astatine	At	(210)	
34	Selenium	Se	78.96*		86	Radon	Rn	(222)	
35	Bromine	Br	79.904	c	87	Francium	Fr	(223)	
36	Krypton	Kr	83.80	e	88	Radium	Ra	226.0254	f, g
37	Rubidium	Rb	85.4678*	c	89	Actinium	Ac	(227)	
38	Strontium	Sr	87.62	g	90	Thorium	Th	232.0381	f, g
39	Yttrium	Y	88.9059	a	91	Protactinium	Pa	231.0359	f
40	Zirconium	Zr	91.22		92	Uranium	U	238.029	b, c, e, g
41	Niobium	Nb	92.9064	a	93	Neptunium	Np	237.0482	f
42	Molybdenum	Mo	95.94*		94	Plutonium	Pu	(244)	
43	Technetium	Tc	(97)		95	Americium	Am	(243)	
44	Ruthenium	Ru	101.07*		96	Curium	Cm	(247)	
45	Rhodium	Rh	102.9055	a	97	Berkelium	Bk	(247)	
46	Palladium	Pd	106.4		98	Californium	Cf	(251)	
47	Silver	Ag	107.868	c	99	Einsteinium	Es	(254)	
48	Cadmium	Cd	112.40		100	Fermium	Fm	(257)	
49	Indium	In	114.82		101	Mendelevium	Md	(258)	
50	Tin	Sn	118.69*		102	Nobelium	No	(255)	
51	Antimony	Sb	121.75*		103	Lawrencium	Lr	(260)	
52	Tellurium	Te	127.60*						

[a] Element with only one stable nuclide.

[b] Element with one predominant isotope (about 99 to 100 per cent abundance); variations in the isotopic composition or errors in its determination have a correspondingly small effect on the value of A_r(E).

[c] Element for which the value of A_r(E) derives its reliability from calibrated measurements (i.e. from comparisons with synthetic mixtures of known isotopic composition).

[d] Element for which known variations in isotopic composition in terrestrial material prevent a more precise atomic weight being given; A_r(E) values should be applicable to any 'normal' material.

[e] Element for which substantial variations in A_r from the value given can occur in commercially available material because of inadvertent or undisclosed change of isotope composition.

[f] Element for which the value of A_r is that of the most commonly available long-lived isotope.

[g] Element for which geological specimens are known in which the element has an anomalous isotopic composition.

overestimated the abundance of ^{64}Ni possibly by a small impurity of ^{64}Zn or $^{48}Ti^{16}O$. Owing to the large difference between $A_r(^{64}Ni)$ and $A_r(Ni)$ a small overestimate of the ^{64}Ni abundance has a relatively large effect on the value of $A_r(Ni)$ determined. Other mass spectrometric values are also consistent with this decision: $A_r(Ni) = 58.700$ Mattraw and Pachucki[6] and $A_r(Ni) = 58.700$ Inghram and Hess[7]. The uncertainty is now estimated to be much less as a result of the lowering of the mass spectroscopic value of $A_r(Ni)$ to that determined chemically. The Commission thus now feels justified in lowering the value of $A_r(Ni)$ to 58.70 and the implied uncertainty to 0.01.

Rhenium has been the subject of a very careful study at the US National Bureau of Standards[8] and this permits a substantial improvement in the value of the atomic weight by the addition of two further significant figures. Before this work the atomic weight of rhenium was listed as 186.2 and this was one of the least precise values for any element (see *Figure 1* of the 1971 Report[1]). Natural rhenium consists of two isotopes ^{185}Re and ^{187}Re, the latter being radioactive with a half-life of 3×10^{10} years or more; this implies that it would take at least 17 million years to alter the atomic weight of rhenium by 1 p.p.m. Two independent calibrated values of the isotopic abundance ratio, based on calibration by synthetic mixtures of the rhenium isotopes, have now been obtained on different instruments: the ratio is $^{185}Re/^{187}Re = 0.59738 \pm 0.00039$ which yields atom percentages of $^{185}Re = 37.398 \pm 0.016$ and $^{187}Re = 62.602 \pm 0.016$. The atomic weight calculated from this isotopic composition is 186.20679 ± 0.00031. The authors have undertaken a very thorough analysis of possible sources of error and their full discussion of all experimental procedures gives confidence in the reliability of their results. A complete survey of the constancy in isotopic composition of this element in nature was not undertaken. Nevertheless, the Commission had considerable confidence in the experience at the NBS over a period of more than ten years and similar observations of the constancy of rhenium from some other laboratories where rhenium filaments are used for mass spectrometry. No major variation in the $^{185}Re/^{187}Re$ ratio among various lots of rhenium from different manufacturers have there been reported. On the basis of this work the Commission recommends the value of 186.207 for the atomic weight of rhenium, with an implied uncertainty of 0.001.

Although only these two changes in atomic weight values were made the decision to make no change for quite a number of other elements was reached only after careful consideration of the evidence. The Commission is conscious of significant work being done currently especially at the US National Bureau of Standards. Techniques which might yield significant new data in the very near future are under surveillance. Quantitative chemical analyses of high precision are being carried out ever more widely. Their accuracy is being limited increasingly by the uncertainties in atomic weight values.

OTHER CHANGES IN THE TABLE

The Commission decided to amplify the heading of the Atomic Weights Table. The new wording is incorporated in the Tables on pages 592 and 594.

In the Tables of Atomic Weights for 1951 and 1955, the mass number of the isotope of longest half-life was listed instead of the atomic weight value of certain radioactive elements. The Commission, however, in later years, decided to abandon this practice because it has a number of disadvantages.

(i) The use of the mass number is too imprecise to be useful for much analytical work.

(ii) Users generally know enough about the source of their material to have the best useable knowledge of the applicable atomic weight.

(iii) New half-life determinations may change the listed isotope. As recently as in 1969, ^{255}No and ^{256}Lr would have been listed whereas now we have to list ^{259}No and ^{260}Lr.

(iv) The isotope of longest half-life in several instances is not the one most widely available, e.g. technetium, plutonium and californium.

Consequently in subsequent years the Commission did not indicate any atomic weight value for these elements. However, the Commission has become increasingly aware that many users were dissatisfied with the omission from the numerical column of any value for now well-known elements, and, after reviewing possible alternatives, the members decided to revert to the former practice.

Another change indicated in the Table heading is the use of the asterisk instead of subscript or small-size numbers to indicate uncertainties of three rather than one in the last digit. The Commission realized that these other methods for indicating uncertainties have caused difficulties for printers and users. The asterisk offers an additional advantage in being computer readable in well established computer languages.

Minor clarification in the wording of the footnotes has been made. Corresponding to their greater importance to chemists, the footnotes this year are given greater prominence. They are set in full size print and the reference to them is made from an additional column of the Table rather than from small superscript letters.

The widespread use of separated stable isotopes of the rare gas elements is leading to the isotopically depleted material reaching commerce. While natural argon contains so little of the 36 and 38 isotopes that their depletion does not greatly affect the atomic weight, the problem is more serious with neon, krypton and xenon in which the atomic weight value may be seriously affected by depleting the element of its rarer but stable isotopes. The footnote ‘e’ has therefore been added to these elements, thereby warning users of possible substantial variation of atomic weight values in commercial materials.

The Commission wishes to emphasize that the greatly increased use of fission-product materials and separated or enriched isotopic materials carries with it the danger that laboratory samples of anomalous isotopic composition could inadvertently be used. For this reason, footnote ‘e’ is appended not only to Ne, Kr and Xe but also, as previously, to Li, B and U. At present the danger for other elements may seem remote, and the Commission does not yet wish to add footnote ‘e’ to H, He, C, N or O, though the increasing use of separated isotopes of these elements for a variety of purposes requires vigilance both in their use and their subsequent disposal.

Footnote ‘g’ has been given additionally to Os, Th and U. For osmium this is because of the occurrence of nearly pure ^{187}Os in rhenium ores from the decay of ^{187}Re. For thorium footnote 'g' is added because of the rare occurrence of almost pure ^{230}Th (ionium) in certain minerals. Footnote 'g' has also been added to uranium. Very small variations in the relative abundance of ^{235}U and relatively large variations in ^{234}U have been previously claimed. However, late in 1972, large variations in the abundance of ^{235}U were reported[9–11], and, as is important to note, assigned to a chain reaction that took place in nature about 2×10^9 years ago[9]. At the Oklo quarry in Gabon it affected thousands of tons of ore. Along with the depletion of ^{235}U through neutron fission, fission products were produced. The discovery of these stable decay products and their anomalous isotopic composition has confirmed this natural phenomenon. Thus neodymium, samarium and europium have been described[10, 11] showing isotopic compositions ranging from that of 'natural' elements to that of fission-produced elements. In the latter case, some stable isotopes that can normally occur in nature, may be totally absent, e.g. Xe isotopes lighter than ^{130}Xe. However, as the Oklo quarry is not a commercial source of these particular elements (except perhaps for uranium) the Commission decided not to add footnote 'g' to the suite of elements of atomic number 32–66 but to warn against the possibility of meeting such anomalies here in the text of the Report.

TERMINOLOGY

The IUPAC Commission on Symbols, Terminology and Units in its *Manual of Symbols and Terminology for Physicochemical Quantities and Units* defines atomic weight (relative atomic mass) of an element as 'the ratio of the average mass per atom of a natural nuclidic composition of an element to $\frac{1}{12}$ of the mass of an atom of nuclide ^{12}C'.

Inherent in this definition is the notion that such a natural nuclidic composition exists to define that atomic weight as a constant at least within the precision achieved by practical chemical measurements. There was indeed a time when such an atomic weight was believed to exist as a universal constant for every element. For all practical purposes such a constancy does indeed apply to all mononuclidic elements (with a single stable nuclide) and for many others for which the isotopic composition appears to be constant within the measured precision for all natural occurrences of 'normal' material. However, the existence of appreciable variations in isotopic composition in some naturally occurring materials has forced the Commission in its Atomic Weights Table to quote values (e.g. for H, Li, B, C, O, Si, S, Ar, Cu, Pb) below the precision easily attainable by modern techniques (see footnote 'd'). It has been possible in some instances to compromise and to avoid excessive loss of precision by a further footnote 'g' warning users of some unusual occurrences outside the normal implied variations (e.g. Li, Mg, Ar, Ca, Sr, Os, Pb, Ra, Th, U). However, the problem is rapidly becoming more serious as the precision and application of meaningful analytical measurements improve. The problem is further exacerbated by the progressively increasing use of materials which have suffered changes in isotopic composition by artificial processes themselves ever more widely employed by industry. The view has also been expressed (for example by De Bièvre[12]) that very precise atomic weights should not be regarded a property of the element as such but that they should be held to apply only to a specified sample of material.

The Commission encourages widespread discussion by chemists not only of this viewpoint, but also of the inherent difficulty of refining the above definition of atomic weight so that it is precise for elements with more than one stable isotope. Should one average the mass per atom over all non-industrially processed non-meteoric terrestrial atoms of that element or merely over those that could with available technology be described as accessible to man? Perhaps we should use some special mean value because of the skew distribution of isotopic compositions. In any event such a definition could frequently not be given an operational meaning to a precision comparable with that attainable experimentally. In science this is a serious problem, and it is usually wise to sharpen the definition and at the same time make it more accessible to experiment.

The Commission does not wish to propose a definitive solution to these basic problems at the present time. Rather, it would welcome suggestions which can be discussed with other interested IUPAC bodies at the 1975 Conference in Spain. Some Commission members hope to publish a tentative proposal to define 'atomic weight' in relation to material to be specified, plus 'atomic weight of an element' using one of the following criteria:

(a) a judiciously chosen number such as the mean between the largest and smallest reliable, known atomic weights for all 'normal' materials
(b) a standard reference material
(c) a mineral from a specified locality of proven homogeneity
(d) a defined isotopic composition.

These suggestions should be coupled with a precise convention linking the tabulated value to the atomic weight of an element and the atomic weights commonly found in nature and in commerce.

DESIGNATION OF WELL CHARACTERIZED MATERIALS

In view of the large variety of materials in commerce which contain elements having an isotopic composition other than 'normal' some manufacturers and users may favor the introduction of precise statements on labels so worded as to minimize misunderstandings and errors in the interpretation of analytical data or inadvertent use of valuable (isotopically enriched) materials for common purposes.

If such labelling is indeed desired on an increasing scale, it might well be thought proper for this Commission to make proposals for relevant wording. The Commission does not wish to put forward such wording at this stage. It does, however, hereby distribute some draft statements to the chemical public and to reagent manufacturers for comment on usefulness, applicability and the tentative wording itself. If there appears to be support for this Commission to disseminate such phrases for labelling, the topic will be more fully discussed during the 1975 Conference.

The draft phrases for labels of well characterized materials are as follows:

(a) 'Atomic Weights Published by IUPAC Applicable'

TABLE OF RELATIVE ATOMIC MASSES OF SELECTED NUCLIDES

Name	Symbol	Atomic number	Mass number	Relative atomic mass[13]	Half-life[14]†	
Hydrogen	H	1	1	1.007825		
(Deuterium)	(D)	1	2	2.014102		
(Tritium)	(T)	1	3	3.016049	12.33	a
Helium	He	2	3	3.016029		
			4	4.00260		
Lithium	Li	3	6	6.01512		
			7	7.01600		
Boron	B	5	10	10.01294		
			11	11.00931		
Carbon	C	6	12	12 Exactly		
			13	13.003355		
			14	14.00324	5.73×10^3	a
Nitrogen	N	7	14	14.003074		
			15	15.00011		
Oxygen	O	8	16	15.994915		
			17	16.999133		
			18	17.99916		
Neon	Ne	10	20	19.99244		
			21	20.99385		
			22	21.99138		
Magnesium	Mg	12	24	23.98504		
			25	24.98584		
			26	25.98259		
Silicon	Si	14	28	27.97693		
			29	28.97650		
			30	29.97377		
Sulfur	S	16	32	31.97207		
			33	32.97146		
			34	33.96787		
			36	35.96708		
Argon	Ar	18	36	35.96755		
			38	37.96273		
			40	39.96238		
Calcium	Ca	20	40	39.96259		
			42	41.9586		
			43	42.9588		
			44	43.9555		
			46	45.9537		
			48	47.9525		
Copper	Cu	29	63	62.9296		
			65	64.9278		
Krypton	Kr	36	78	77.9204		
			80	79.9164		
			82	81.9135		
			83	82.9141		
			84	83.9115		
			86	85.9106		
Strontium	Sr	38	84	83.9134		
			86	85.9093		
			87	86.9089		
			88	87.9056		
Technetium	Tc	43	97	96.9064	2.6×10^6	a
			99	98.9062	2.13×10^5	a

TABLE OF RELATIVE ATOMIC MASSES OF SELECTED NUCLIDES

Name	Symbol	Atomic number	Mass number	Relative atomic mass[13]	Half-life[14]†	
Xenon	Xe	54	124	123.9061		
			126	125.9043		
			128	127.9035		
			129	128.9048		
			130	129.9035		
			131	130.9051		
			132	131.9041		
			134	133.9054		
			136	135.9072		
Promethium	Pm	61	145	144.9128	18	a
			147	146.9152	2.6234	a
Osmium	Os	76	184	183.9526		
			186	185.9539		
			187	186.9558		
			188	187.9559		
			189	188.9582		
			190	189.9585		
			192	191.9615		
Lead	Pb	82	204	203.9730		
			206	205.9745		
			207	206.9759		
			208	207.9766		
Polonium	Po	84	209	208.9824	102	a
			210	209.9829	138.38	d
Astatine	At	85	210	209.987	8.1	hr
Radon	Rn	86	222	222.0176	3.824	d
Francium	Fr	87	223	223.0197	22	min
Radium	Ra	88	226	226.0254	1.60×10^3	a
Actinium	Ac	89	227	227.0278	21.77	a
Thorium	Th	90	230	230.0331	7.7×10^4	a
			232	232.0381	1.40×10^{10}	a
Protactinium	Pa	91	231	231.0359	3.25×10^4	a
Uranium	U	92	233	233.0397	1.58×10^5	a
			234	234.0409	2.44×10^5	a
			235	235.0439	7.04×10^8	a
			236	236.0456	2.34×10^7	a
			238	238.0508	4.47×10^9	a
Neptunium	Np	93	237	237.0482	2.14×10^6	a
Plutonium	Pu	94	238	238.0496	87.8	a
			239	239.0522	2.439×10^4	a
			240	240.0538	6.54×10^3	a
			241	241.0568	15	a
			242	242.0587	3.87×10^5	a
			244	244.0642	8.3×10^7	a
Americium	Am	95	241	241·0568	433	a
			243	243.0614	7.37×10^3	a
Curium	Cm	96	242	242.0588	163	d
			243	243.0614	28	a
			244	244.0627	18.1	a
			245	245.0655	8.5×10^3	a
			246	246.0672	4.76×10^3	a
			247	247.0703	1.54×10^7	a
			248	248.0723	3.5×10^5	a
			250	250.0784	1.1×10^4	a

† a = year; d = day; hr = hour; min = minute.

Continued overleaf

TABLE OF RELATIVE ATOMIC MASSES OF SELECTED NUCLIDES (CONT.)

Name	Symbol	Atomic number	Mass number	Relative atomic mass[13]	Half-life[14]†	
Berkelium	Bk	97	247	247.0703	1.4×10^{3}	a
			249	249.0750	311	d
Californium	Cf	98	251	251.0796	900	a
			252	252.0816	2.63	a
			254	254.0874	6×10	d
Einsteinium	Es	99	253	253.0848	20.47	d
			254	254.0880	276	d
Fermium	Fm	100	257	257.0951	100.5	d

†a = year; d = day.

This statement would be understood to mean that every element present as major constituent has been either:

derived from a naturally occurring source by processes none of which is suspected of causing significant isotopic separation or nuclear reaction: and/or

subjected to atomic weight measurements to a stated precision and found to agree with the latest IUPAC values for those elements.

(b) '<u>Atomic Weight Published by IUPAC Inapplicable for Element(s) . . . . for which A_r(E) = ...</u>'

This statement would be intended to convey the following meaning:

In this material the element(s) specified differ in atomic weight(s) from those in the latest Table of Atomic Weights, and the measured values are given by:

$$A_r(\text{Element}) = \ldots\ldots\ldots$$
$$\ldots\ldots\ldots\ldots = \ldots\ldots\ldots$$

For the other elements (if any) present as major constituents the published atomic weights are applicable.

The labelling of separated stable isotopes or radioisotopes is held not to concern this Commission. However, there may be cases in which a material may contain an element the specific atomic weight of which—though within the range implied by the tabulated value—is known with greater accuracy than is implied by the value in the Table of Atomic Weights. This might occur especially when the tabulated value has to accommodate wide variations in natural occurrences.

In such instances the label on the material might read:

(c) '<u>The actual atomic weight of the element . . . . in this particular sample is . . . .</u>'

The meaning of this phrase would be self evident.

Comments on these suggestions are invited and should be directed to the Secretary of the Commission:

H. Steffen Peiser
National Bureau of Standards
Washington, DC 20234, USA

RELATIVE ATOMIC MASSES OF SELECTED NUCLIDES

The principles by which the Table of Relative Atomic Masses of Selected Nuclides was prepared for the 1971 Report[1] have been found to be satisfactory and have not been changed for this 1973 Report. However, the additional footnotes in the 1973 Table of Atomic Weights, namely 'e' for Ne, Kr and Xe and 'g' for Os, Th and U have necessitated considerable expansion of the 1973 Table of Relative Atomic Masses of Selected Nuclides in order to accommodate the isotopes of these elements.

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