CONTENTS.

METALWORKING.

INTRODUCTION.

The Scope and Object of this Book.

Metalworking is only limited in its subject matter to the extent that its processes are hand-wrought as distinguished from those for which machinery is employed, and that metal is the material worked upon. An idea of the wide scope of the book may be inferred from an outline of its contents. Metalworking in all branches of practical handicraft will be fully dealt with. First comes a concise though comprehensive table showing at a glance the physical qualities of all metals, their specific weights, their strength, their melting points, etc. This is followed by explanations of the first principles of metalworking in the foundry, at the forge, at the vice, and in the lathe. Then will be described in detail general processes employed in metalworking—such as jointing, soldering, drilling, polishing, and lacquering. Electro-metallurgy is included. Those elements of metalworking that are common to many handicrafts having been disposed of, the tools used in metalworking will be illustrated, and how to make them will be explained. Next will follow a large and varied collection of graded examples of work, each one clearly illustrated and described in minute detail. These examples will be typical of the specialised handicrafts of many widely different trades, including wireworking, lathe-building, gunsmithing, motor-building, electroplating, goldsmithing, art metalworking, cutlery, electric bell making, jewellers' work, etc. The contents of this book range from the rudimentary teaching required by the tyro to the construction of high-class examples that will interest the adept craftsman.

Cast and Wrought Metals.

Metalwork of all kinds is readily divisible into two broad classes—cast and hammered. This distinction is sufficient for general purposes, although it does not entirely cover the field, because nearly all malleable iron made by modern processes, and all mild steel, are cast before they are puddled, hammered, or rolled. Neither does it include the method of electrotyping. Both casting and hammering were employed in prehistoric ages, and both methods have continued in use until the present time. Whilst it is comparatively easy to produce intricate forms by casting, the forging of similar forms taxes the very highest skill and patience of the hammerman. Most of the specimens of prehistoric art in metalworking which have been preserved to us are in the form of castings, but the more delicate hammered works are mostly of historic dates. The work of the blacksmith is of comparatively recent origin. Skill in the working of iron dates only from a few centuries before the Christian era. Previous to the introduction of iron, bronze was the metal employed for weapons of war and defence, and for articles of ornament and domestic service. The ancients had acquired very great skill in the composition and use of this alloy, as is proved by the vast number of cutting tools and utensils that have been brought to light by the researches of archæologists.

The Age of Bronze.

The origin of the age of bronze is lost in remote antiquity. No hard chronological line separates it from the preceding neolithic or new stone age. But the discovery of the use of copper and tin marked a most distinct advance in the history of civilisation; and in this broad sense the bronze-using period may be regarded as a very important age or era in the history of mankind. It is considered probable, and in some isolated districts it is a fact, that there was also a period when pure copper was employed, unalloyed with tin. But the advantages in increased hardness which were gained by alloying tin with copper were so evident, that in most cases bronze, and not pure copper, was used; and as a matter of fact, nearly all the primitive implements of metal as yet found in the old world are made of alloys of copper and tin. The composition of the prehistoric bronzes varied extremely. A good bronze mixture, as used by modern engineers, contains about 88 or 89 of copper to 12 or 11 of tin respectively. Many of the ancient bronzes contained proportions approximating to these, but some contained a much less, some also a much greater proportion of copper. Very considerable traces of lead, nickel, silver, and iron also occur in the early bronzes, the modern art of separating copper from foreign ingredients present in the ores being unknown to the early smelters. In no essential did the earliest known methods of moulding and casting differ from those carried on at the present day. Yet relics have been found that date from a period long anterior to the Christian era; probably many are from 2,000 to 4,000 years old. It has been thought that the bronze age began in England some 1,200 or 1,400 years B.C., and that it lasted about a thousand years, but the knowledge of copper and tin may have been much earlier.

Importance and Value of Iron.

Iron is the most important of all the metals, though the least costly. It is more valuable than any of the precious metals in its usefulness to us. We are at the present time so dependent on iron that it is really difficult for us to imagine a time without iron. Cast-iron is the crude metal derived from the smelting furnace, and imperfectly freed from impurities. Wrought-iron, with which we are directly concerned, is the pure form of the metal, in colour a metallic, steely grey, but it rusts very rapidly on exposure to damp. In iron we possess a substance which is at once hard, malleable, able to bear a great strain, and yet can be made very brittle; it is also inflexible, so that the most elastic springs can be formed from it. It can also be made to form the thick, heavy ribs and plating of the vessel of war, the slender blade of the surgeon's knife, or the exquisitely artistic and beautiful scroll and leaf work of the chancel screen, the altar railing, or the grille. Iron possesses, in fact, qualities so varied, vast, and useful as at once to mark it out as the central figure amongst the productions of earth. It appears to be quite certain that so important a metal was known from the very earliest times—at least, as far as regards some of its uses. In the early books of the Bible we read continually of iron in various forms and for various uses—domestic and social; also for weapons of war—as iron axes, iron swords, etc.

The Superiority of Wrought-iron.

There are certain qualities possessed by wrought-iron when hammered or rolled out which give it a great superiority over cast-iron for ornamental work and other work where there is no very considerable bulk. First, then, a fibrous texture, rendering it tough in working and able to be bent about in various shapes without cracking or breaking; then again its malleability, enabling the bar of iron to be drawn out or flattened into the required forms; again, its ductility, enabling a thick bar to be drawn out to the very thinnest of wire, or rolled out to the thinnest of sheet. Then again, and lastly, its most valuable quality for our purpose—the quality which we call welding, or the property of uniting together at a heat below the melting point, thus enabling ornamental effects to be produced with the metal alone without having patterns, etc.

The combination of these various qualities in one substance enables the production of ornamental and other effects in iron which would be impossible in any other metal known to us, and without which the smith's art and work would never have been brought into existence. The separate

METALS.

METAL.	Symbol.	Colour.	Derivation of Name.	Discoverer.	Date.	Atom. Wght. (new s'tem)	Specific Gravity.	Specific Heat at 0 C.	Electrical Conduc-tivity. Hg at 0 C.	Heat Conduc-tivity. Silver = 100.
Aluminium ..	Al	Tin-white	Latin: alumen (alum)	Wöhler	1828	27·1	2·56	·2253	20·97	31·33
Antimony ..	Sb	Silver-white	Latin: stibium	Valentine	1490	120·43	6·697	·0523	2·05	4·03
Arsenic ..	As	Steel-grey				75·01	5·727	·083	2·679	
Barium ..	Ba	Ylwsh.-white	Greek: baros (heavy)	Davy	1808	137·43	3·5–4			
Bismuth ..	Bi	White		Agricola	1530	208·11	9·759	·0305 at 20°	·8676	1·8
Cadmium ..	Cd	White, blue tinge	Greek: cadmia (calamin)	Stromeyer	1817	112·3	8·65–8·8	·0548	13·46	20·06
Cæsium ..	Cs	Silver-white	Latin: cæsius (bluish-grey)	Bunsen and Kischhoff	1860	132·9	1·88			
Calcium ..	Ca	Ylwsh.-white	Latin: calx (lime)	Davy	1808	40	1·82	·1686	12·5	25·4
Cerium ..	Ce	Steel-grey	Planet Ceres	Klaproth, Hisinger, and Berzelius	1803	140	5·5	·04479		
Chromium ..	Cr	Greyish-white	Greek: chroma (colour)	Vanquelin	1797	52·45	6·8–7·3	·0998		
Cobalt ..	Co	Steel-grey	German: kobold (goblin)	Brandt	1735	58·8	8·52–8·95	·107	9·685	17·2
Copper ..	Cu	Reddish-ylw.	Latin: Cuprum (Cyprian)			63	8·36–8·95	·0933	52 to 54	73·6
Didymium ..	Di + Pr	White	Greek: didymus (double)	Mosander	1842	142	6·544	·04563		
Erbium ..	Er					166				
Gallium ..	Ga	Silver-white	Latin: Gallia (Gaul)	Lecoq de Boisbaudran	1875	70	5·96	·079		
Germanium	Ge	Greyish-white	Latin: Germania (German)	Winkler	1885	72·3	5·469	·0737		
Glucinum* ..	Be or Gl	Steel-colord.	Greek: glukus (sweet)	Wöhler	1827	9·08	2·1	·4702		
Gold	Au	Yellow	Hebrew			196·5	19·3	·0316	43·84	53·2
Indium ..	In	Silver-white	Latin: indicum (indigo)	Reich	1863	113·4	7·4	·05695		
Iridium ..	Ir	Grey	Latin: iris (rainbow)	Tennant	1803	192·5	22·38	·0323		
Iron	Fe	Greyish-white	Latin: ferrum			56	6·95–8·2	·114	9·68	11·9
Lanthanum	La	White	Greek: lanthancin (conceal)	Mosander	1839	138·5	6·163	·04485		
Lead	Pb	Blue-grey	Latin: plumbum			206·4	11·4	·03065	4·8	8·5
Lithium ..	Li	Silver-white	Greek: lithos (stone)	Arfvesson	1817	7·03	0·578–0·589	·9408	10·69	
Magnesium ..	Mg	Silver-white	Magnesia in Asia Minor	Davy	1808	24·36	1·75	20°–51·245°	22·84	34·3
Manganese ..	Mn	White-grey	Magnesia in Asia Minor	Gahn	1740	55·02	8	14°–97°		
Mercury ..	Hg	White	The Deity and planet Mercury			200	13·6	·033	1	5·3
Molybdenum	Mo	Dull silver	Greek: molybdos (lead)	Hjelm	1782	96	8·62	·0659		
Neodymium	Nd					143·6				
Nickel ..	Ni	White	German: kupfernickel	Cronstedt	1751	58·7	8·3–8·7	·10916	7·374	
Niobium† ..	Nb	Steel-grey	Niobe	H. Rose	1841	94	4·06			
Osmium ..	Os	Blue-white	Greek: osmē (odour)	Tennant	1803	190·8	22·477	·03113		
Palladium ..	Pd	White	Planet Pallas	Wollaston	1803	106·5	11·4	·0582		
Platinum ..	Pt	White	Spanish: platæ (silver)	Woods	1741	194·5	21·5	·0314	8·042 Ag = 100	37·9
Potassium ..	K	Silver-white	Potash	Davy	1807	39·04	0·875	·166	11·23	45
Praseodymium	Pr					140·5		·0314		
Rhodium ..	Rh	Bluish-white	Greek: rhodon (a rose)	Wollaston	1803	102·7	12·1	·05803		
Rubidium ..	Rb	White	Ruber (dark red)	Bunsen	1860	85·2	1·52			
Ruthenium ..	Ru	White	Rutheria (Russia)	Claus	1843	101·4	12·261	·0611		
Samarium ..	Sm		Samerskite	Lecoq de Boisbaudran		150				
Scandium ..	Sc			Nilson	1879	44				
Silver	Ag	White				107·66	10·4–10·7	·0557	63·845	100
Sodium ..	Na	Silver-white	Latin: salsola (soda)	Davy	1807	22·995	0·9735	·2734	18·3	36·5
Strontium ..	Sr	Ylwsh.-white	Strontian, a village in Argyllshire		1790	87·3	2·542			
Tantalum ..	Ta			Eheberg	1802	183	10·8			
Tellurium ..	Te	White shining semi-metal				127·49	6·255	·0475	·000777 Ag at 0° = 1	
Terbium ..	Tr			Muller	1782	160				
Thallium ..	Tl	White	Greek: thallus (green)	Crookes	1861	203·64	11·88	·0325	5·225	
Thorium ..	Th	Greyish-white	Scandinavian god Thor	Berzelius	1828	232	11·1–11·23	·02787		
Tin	Sn	Silver-white	Latin: stannum (tin)			119	7·3	·0559	8·726	15·2
Titanium ..	Ti	Dark-grey	God Titan	Klaproth	1795	47·9	3·5888	·1135		
Tungsten ..	W	Steel-grey	Swedish: tungsten (heavy stone)	J. and F. d'Elhujar	1785	184·4	18·77	·035		
Uranium ..	U	Silver-white	The Deity and planet Uranus	Klaproth	1789	240	18·7	·0276		
Vanadium ..	V	Light-grey	Scandinavian: Vanadis, deity	Sefström	1830	51·4	5·5			
Ytterbium ..	Yb		Swedish: Ytterby (town in Sweden)	Marignac	1878	173				
Yttrium ..	Y		Swedish: Ytterby (town in Sweden)			89				
Zinc	Zn	Bluish-white	German: Zink (zinc)	Paracelsus	1541	65·4	6·9–7·15	·0935		
Zirconium ..	Zr	Grey	Persian: Zargun (gold coloured)	Klaproth	1789	90·5	4·15	·066		

Several earth metals are omitted from table, as Samarium, Gadolinium, Neon, Xenon, etc.

* Also called Beryllium. † Also called Columbium.

pieces, when they leave the forge, may be fastened together with straps of heated iron tried round them, with bolts, screws, and rivets, or, where really required, may be fixed together with brass or silver solder. These little details will show that wrought-iron is a material that can practically be used almost as fancy wills, to make either the strongest and most massive, or the finest and most beautiful, work.

Malleability, Ductility, and Tenacity.

At this stage it will be well to note these leading characteristics of the metals:—Malleability is the capability of being extended without cracking or breaking, and for the various metals in general use is shown in the following list in order, the most malleable metal being placed first: Gold, silver, copper, tin, lead, zinc, iron, and nickel. Ductility is the property of being drawn into wire, and the metals are ranged in the following order: Gold, silver, iron, copper, nickel, zinc, tin, and lead. Tenacity, or tensile strength, is resistance to being pulled asunder; it is a variable quantity; crystalline construction is often accompanied by brittleness, and fibrous construction by high tenacity, and these are generally diminished by a rise in the temperature of the metal, while the reverse is often the case with regard to malleability and ductility. Metals with feeble tenacity are known as brittle; this quality may be due to hardness or to molecular construction. The following list places the metals in order of tensile strength: iron, nickel, copper, silver, gold, zinc, tin, and lead.

Weights of Metals per Foot and Inch Cube.

The following list, which gives the weights of most ordinary metals and alloys, will be useful. Weights per cubic foot: Brass, 520 lb.; copper, 549 lb.; nickel, 518 lb.; zinc, 429 lb.; aluminium, 160 lb.; lead, 710 lb.; antimony, 420 lb.; tin, 456 lb.; gunmetal, 544 lb.; and magnolia, 650 lb. Weights per cubic inch: Brass, ·3 lb.; copper, ·318 lb.; nickel, ·318 lb.; zinc, ·248 lb.; aluminium, ·093 lb.; lead, ·41 lb.; antimony, ·242 lb.; tin, ·264 lb.; gunmetal, ·315 lb.; and magnolia, ·376 lb.

Materials for the Metalworker.

On p. 3 is given, in tabulated form, the most useful particulars of all known metals. Some of the metals tabulated are known only in the restricted field of scientific research. It is, however, useful for the metalworker to have a complete list for reference, and extended particulars of metals and alloys of general use in the arts are given in later pages of this book.