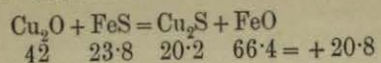
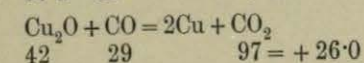
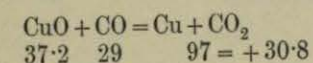
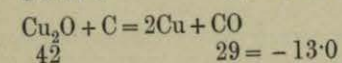
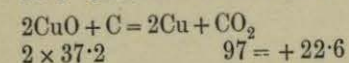
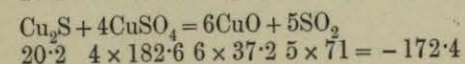
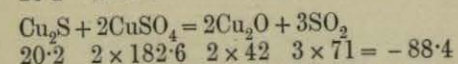
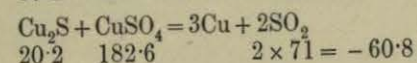
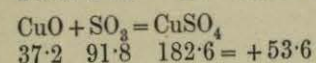
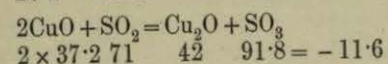
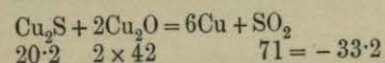
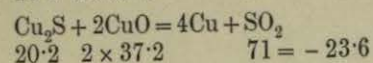
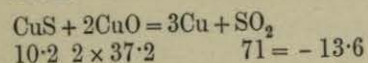
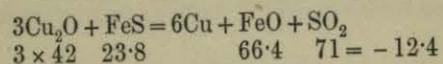


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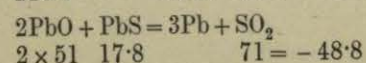
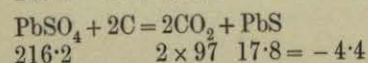
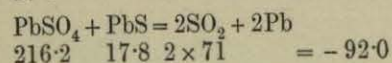
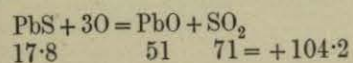


When heated in presence of silica,  $\text{Fe}_2\text{SiO}_4$  is formed

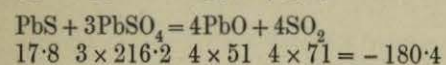
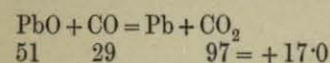
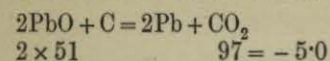
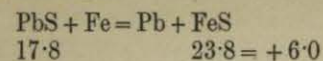


## III.

## Lead.

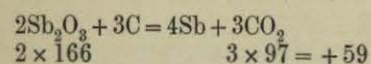
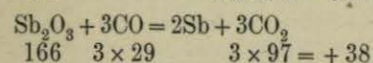
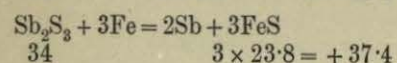
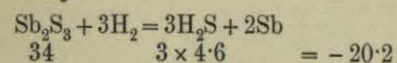


## Lead—continued.



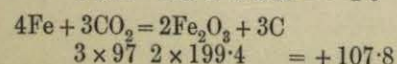
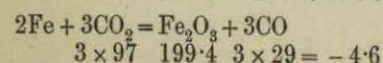
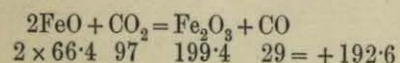
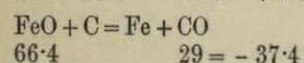
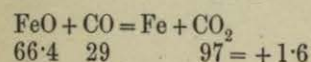
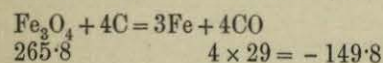
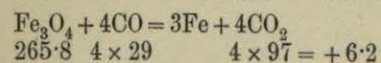
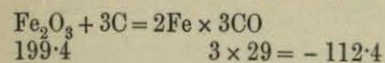
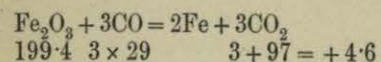
## IV.

## Antimony.

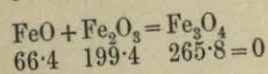
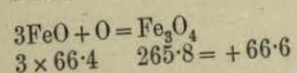
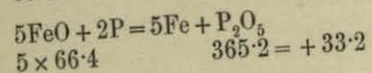
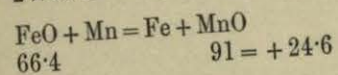
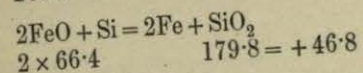
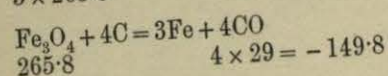
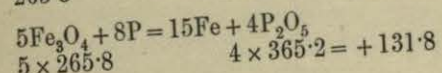
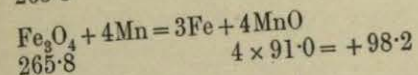
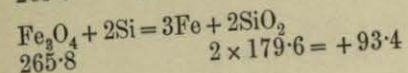
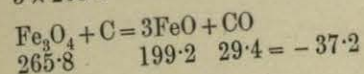
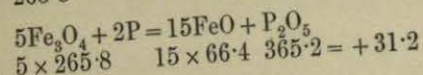
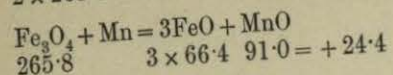
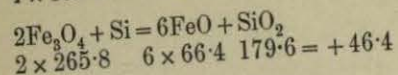
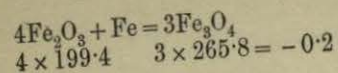
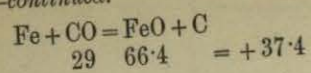


## V.

## Iron.

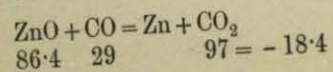
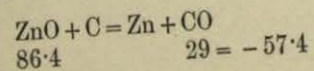


## Iron—continued.



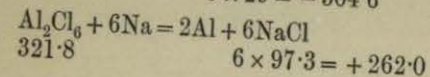
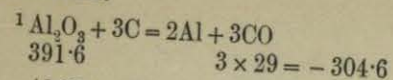
## VI.

## Zinc.



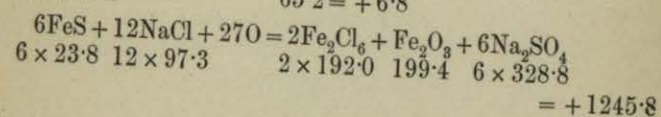
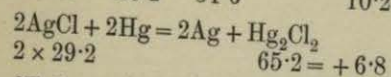
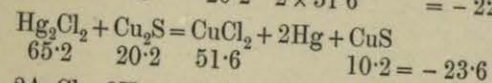
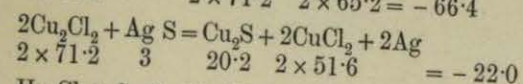
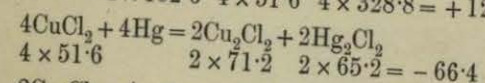
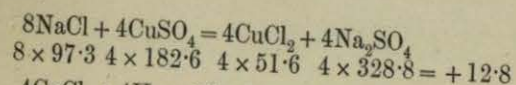
## VII.

## Aluminium.



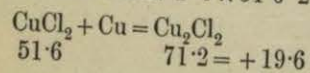
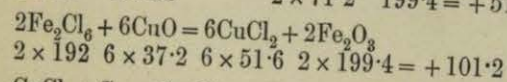
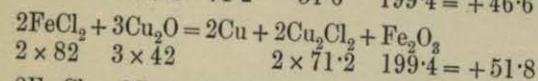
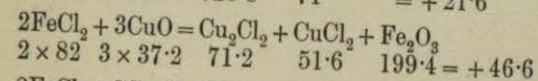
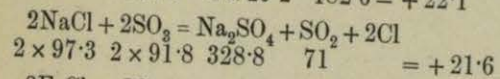
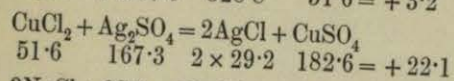
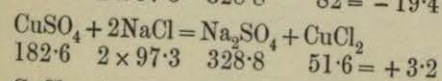
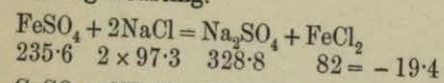
## VIII.

## Silver.



## IX.

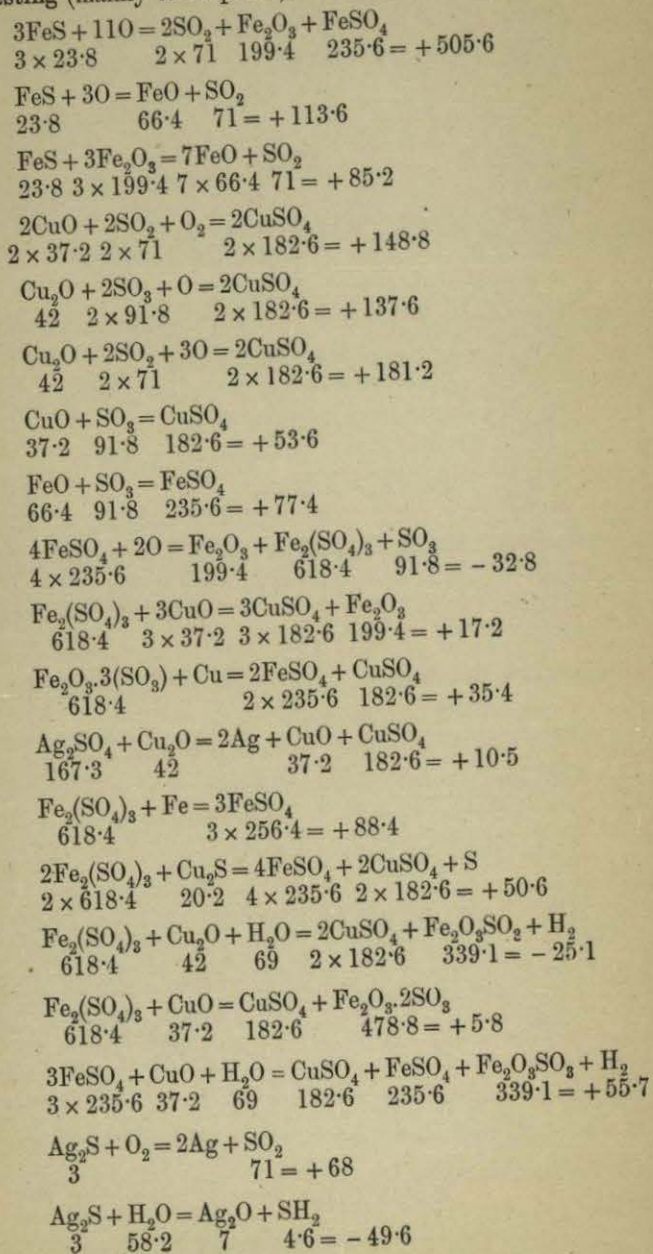
## Chloridising Roasting.



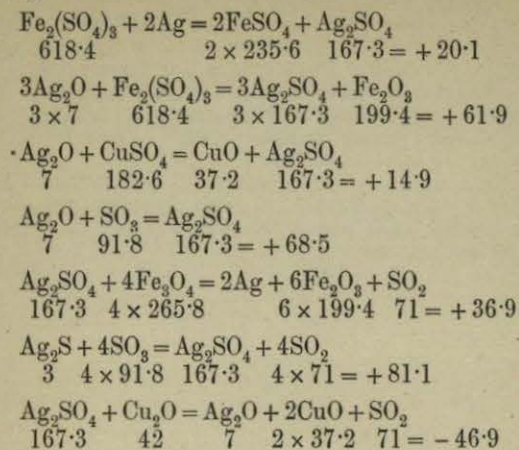
<sup>1</sup> Fremy, *Encyclopédie Chimique*, Paris, 1890.

## X.

Roasting (mainly to Sulphate).

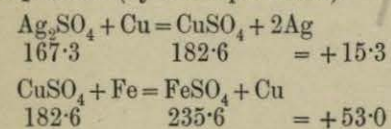


Roasting—continued.



## XI.

Precipitation (by a cheaper metal).



See also III. and IV. for cases of precipitation in the dry way of lead and antimony, from their sulphides, by iron.

The table given on the folding plate will enable the student to form other thermal equations for himself.

In calculating the heats of formation of the basic ferric sulphates, it has been necessary to assume that the heat evolved is proportional to the ratio of acid to base. It must be remembered that in the case of the combination of carbon and oxygen such a relationship does not exist.

## BIBLIOGRAPHY.

- Berthelot.—*Essai de Mécanique Chimique* (Paris, 1879); *Traité Pratique de Calorimétrie Chimique* (Paris).  
 H. Le Chatelier.—*Equilibres Chimiques* (see Comptes Rendus, vol. cvi., 1888, pp. 355, 598, 1008).  
 Prof. A. Ditte.—*Leçons sur les Métaux* (Paris, 1891).  
 P. Duhem.—*Introduction à la Mécanique Chimique* (Paris, 1893).  
 J. Willard Gibbs.—*On the Equilibrium of Heterogeneous Substances* (Trans. Connecticut Acad., vol. iii.).



TABLE SHOWING HEATS OF FORMATION OF THE PRINCIPAL METALLIC COMPOUNDS.

METAL.	OXIDES.		SULPHIDE.		SULPHATES.		SELENIDES AND TELLURIDES.		FLUORIDES.		CHLORIDES.		BROMIDES (FROM LIQUID BROMINE).		IODIDES (FROM SOLID IODINE).		CYANIDES.*		CARBONATES.	
	Solid.	Dissolved.	Solid.	Dissolved.	Solid.	Dissolved.	Solid.	Dissolved.	Solid.	Dissolved.	Solid.	Dissolved.	Solid.	Dissolved.	Solid.	Dissolved.	Solid.	Dissolved.	Solid.	Dissolved.
ALUMINIUM	Al <sub>2</sub> O <sub>3</sub> ·3H <sub>2</sub> O 391·6	...	Al <sub>2</sub> S <sub>3</sub> 124·4	...	...	...	...	...	...	...	AlCl <sub>3</sub> 321·8	475·6	Al <sub>2</sub> Br <sub>6</sub> 239·4	410·0	Al <sub>2</sub> I <sub>6</sub> 140·2	319·6	...	...	...	...
AMMONIUM	...	...	...	...	(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> 282·2	279·6	...	...	NH <sub>4</sub> F 87·7	85·6	NH <sub>4</sub> Cl 76·7	72·7	NH <sub>4</sub> Br 71·2	66·9	NH <sub>4</sub> I 50·6	47·1	NH <sub>4</sub> CN † 40·5	36·1	...	...
ANTIMONY	Sb <sub>2</sub> O <sub>3</sub> 166	...	Sb <sub>2</sub> S <sub>3</sub> 34	...	...	...	...	...	Sb <sub>2</sub> F <sub>6</sub> 277·6	...	SbCl <sub>3</sub> 91·4	...	SbBr <sub>3</sub> 76·9	...	SbI <sub>3</sub> 29·2	...	...	...	...	...
ARSENIC	As <sub>2</sub> O <sub>3</sub> 154·7	147·1	...	...	...	...	...	...	...	...	AsCl <sub>3</sub> 71·5	...	AsBr <sub>3</sub> 44·9	...	AsI <sub>3</sub> 12·7	...	...	...	...	...
ARSENIC	As <sub>2</sub> O <sub>5</sub> 219·4	225·4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
BARIUM	BaO 124·2	158·7	BaS 98·3	109·8	BaSO <sub>4</sub> 338·1	...	BaSe 69·9	...	BaF <sub>2</sub> 224	221·5	BaCl <sub>2</sub> 194·7	...	BaBr <sub>2</sub> 170	...	...	...	...	...	...	...
BISMUTH	Bi <sub>2</sub> O <sub>3</sub> 137·8	...	...	...	...	...	...	...	...	...	BiCl <sub>3</sub> 90·8	...	...	...	...	...	...	...	...	...
BISMUTH	Bi(OH) <sub>3</sub> 171·7	...	...	...	...	...	...	...	...	...	BiOCl 88·2	...	...	...	...	...	...	...	...	...
CADMIUM	Cd(OH) <sub>2</sub> 66·4	...	CdS 34	...	CdSO <sub>4</sub> 221·2	...	CdSe 23·7	...	...	...	CdCl <sub>2</sub> 98·2	96·2	CdBr <sub>2</sub> 75·2	75·6	CdI <sub>2</sub> 48·8	47·8	Cd(CN) <sub>2</sub> 40	...	CdCO <sub>3</sub> 84·9	...
CADMIUM	CdTe 20	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
CALCIUM	CaO 132	150·1	CaS 92	98	CaSO <sub>4</sub> 318·4	...	CaSe 70·2	...	CaF <sub>2</sub> 219·8	...	CaCl <sub>2</sub> 169·8	187·2	CaBr <sub>2</sub> 143·6	168	CaI <sub>2</sub> 107·8	135·4	...	Ca(CN) <sub>2</sub> (Aq) 115·4	CaCO <sub>3</sub> 172·4	...
COBALT	Co(OH) <sub>2</sub> 64	...	CoS(Aq) 19·7	...	CoSO <sub>4</sub> (Aq) 230·5	...	CoSe 13·9	...	...	...	CoCl <sub>2</sub> 76·4	94·8	...	...	...	...	...	...	...	...
COBALT	CoTe 15·2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
COPPER	Cu <sub>2</sub> O 42	...	Cu <sub>2</sub> S 20·2	...	CuSO <sub>4</sub> 182·6	198·4	Cu <sub>2</sub> Se 9·6	...	...	...	Cu <sub>2</sub> Cl <sub>2</sub> 71·2	...	Cu <sub>2</sub> Br <sub>2</sub> 50	...	Cu <sub>2</sub> I <sub>2</sub> 32·5	...	...	...	...	...
COPPER	CuO 37·2	...	CuS 10·2	...	...	...	Cu <sub>2</sub> Te 14·2	...	...	...	CuCl <sub>2</sub> 51·6	62·7	CuBr <sub>2</sub> 34·8	43	...	...	...	...	...	...
GOLD	...	Au <sub>2</sub> O <sub>3</sub> Aq 13·2	...	...	...	...	...	...	...	...	AuCl <sub>3</sub> 22·8	27·3	AuBr <sub>3</sub> 12·1	8·4	AuI -5·5	...	...	...	...	...
IRON	FeO † 66·4	...	FeS 23·8	...	FeSO <sub>4</sub> (Aq) 235·6	...	FeSe 15·6	...	...	...	FeCl <sub>2</sub> 82	100	FeBr <sub>2</sub> (Aq) 80·8	...	FeI <sub>2</sub> (Aq) 46·4	...	...	...	...	...
IRON	Fe(OH) <sub>2</sub> † 68·3	...	...	...	Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> (Aq) 618·4	...	FeTe 15·6	...	...	...	FeCl <sub>3</sub> 192	255·4	FeBr <sub>3</sub> (Aq) 96·8	...	...	...	...	...	...	...
IRON	Fe <sub>2</sub> (OH) <sub>6</sub> † 198·2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
IRON	Fe <sub>2</sub> O <sub>3</sub> † 199·4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
IRON	Fe <sub>3</sub> O <sub>4</sub> † 265·8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
LEAD	PbO 51	...	PbS 17·8	...	PbSO <sub>4</sub> 216·2	...	PbSe 17	...	PbF <sub>2</sub> 92·4	...	PbCl <sub>2</sub> 85·2	78·4	PbBr <sub>2</sub> 69	59	PbI <sub>2</sub> 42·0	...	...	...	PbCO <sub>3</sub> 69·4	...
LEAD	PbTe 11·4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
MAGNESIUM	MgO 143·9	148·8	MgS 79·6	...	MgSO <sub>4</sub> 302·3	322·6	...	...	MgF <sub>2</sub> 212·8	...	MgCl <sub>2</sub> 151	187	...	...	...	...	...	...	MgCO <sub>3</sub> 170·6	...
MANGANESE	MnO 91	...	MnS 45·2	...	MnSO <sub>4</sub> 249·9	...	MnSe 22·4	...	...	...	MnCl <sub>2</sub> 112	128	...	...	...	...	...	...	MnCO <sub>3</sub> 113·9	...
MANGANESE	MnO <sub>2</sub> 116·2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
MERCURY	Hg <sub>2</sub> O 24·8	...	HgS 8·2	...	HgSO <sub>4</sub> 165·1	...	HgSe 6·3	...	...	...	Hg <sub>2</sub> Cl <sub>2</sub> 65·2	...	Hg <sub>2</sub> Br <sub>2</sub> 50·9	...	Hg <sub>2</sub> I <sub>2</sub> 31·1	...	...	...	...	...
MERCURY	HgO 22	...	...	...	Hg <sub>2</sub> SO <sub>4</sub> 175	...	...	...	...	...	HgCl <sub>2</sub> 54·5	51·2	HgBr <sub>2</sub> 41·9	...	HgI <sub>2</sub> 25·6	...	Hg(CN) <sub>2</sub> 10·3	7·3	...	...
NICKEL	NiO 61	...	NiS 19·4	...	NiSO <sub>4</sub> (Aq) 229·4	...	NiSe 14·8	...	...	...	NiCl <sub>2</sub> 74·6	97·3	...	...	...	...	...	...	...	...
NICKEL	NiTe 15	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
PALLADIUM	Pd(OH) <sub>2</sub> 20	...	...	...	...	...	...	...	...	...	PdCl <sub>2</sub> 40·4	...	PdBr <sub>2</sub> 24·8	...	PdI <sub>2</sub> 13·4	...	Pd(CN) <sub>2</sub> 23·6	...	...	...
PLATINUM	PtO 15·0	...	...	...	...	...	...	...	...	...	PtCl <sub>4</sub> 59·8	79·4	...	...	...	...	...	...	...	...
PLATINUM	...	...	...	...	...	...	...	...	...	...	PtH <sub>2</sub> Cl <sub>6</sub> (Aq) 163·2	...	PtH <sub>2</sub> Br <sub>6</sub> (Aq) 113·8	...	...	...	...	...	...	...
POTASSIUM	K <sub>2</sub> O 97·2	164·6	K <sub>2</sub> S 101·2	112·4	K <sub>2</sub> SO <sub>4</sub> 344·6	338·2	K <sub>2</sub> Se 90·6	99·2	KF 111·1	108·1	KCl 105	100·8	KBr 96·4	91	KI 80	74·7	KCN 67·6	64·7	K <sub>2</sub> CO <sub>3</sub> 180·8	...
SILVER	Ag <sub>2</sub> O 7	...	Ag <sub>2</sub> S 3	...	Ag <sub>2</sub> SO <sub>4</sub> 167·3	162·8	Ag <sub>2</sub> Se 2	...	AgF 30·9	25·7	AgCl 29·4	...	AgBr 22·7	...	AgI 13·8	...	AgCN 3·6	...	Ag <sub>2</sub> CO <sub>3</sub> 23·4	...
SODIUM	Na <sub>2</sub> O 100·2	155·2	Na <sub>2</sub> S 88·4	103·2	Na <sub>2</sub> SO <sub>4</sub> 328·8	329	Na <sub>2</sub> Se 71·2	89·8	NaF 110·8	110·6	NaCl 97·3	96·2	NaBr 86·7	86·4	NaI 68·8	70·1	NaCN 60·4	59·9	Na <sub>2</sub> CO <sub>3</sub> 175·7	...
TIN	SnO 66·2	...	...	...	...	...	...	...	...	...	SnCl <sub>2</sub> 80·4	81·2	SnBr <sub>2</sub> 63	...	...	...	...	...	...	...
TIN	SnO <sub>2</sub> 137·2	...	...	...	...	...	...	...	...	...	SnCl <sub>4</sub> (liquid) 127·3	157·2	SnBr <sub>4</sub> 93·4	118	...	...	...	...	...	...
ZINC	ZnO 86·4	...	ZnS 43	...	ZnSO <sub>4</sub> 230	248·5	ZnSe 40·4	34	...	...	ZnCl <sub>2</sub> 97·2	112·8	ZnBr <sub>2</sub> 78·2	93·2	ZnI <sub>2</sub> 49·2	60·6	Zn(CN) <sub>2</sub> 53·4	...	ZnCO <sub>3</sub> 97·2	...
ZINC	ZnTe 37·2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

\* From Cyanogen.

† From Nitrogen, Hydrogen, and Cyanogen.

‡ Calculated from Andrews' Value, 265·8 for Fe<sub>3</sub>O<sub>4</sub>.

## CHAPTER XII.

## TYPICAL METALLURGICAL PROCESSES.

**Classification of Processes.**—The methods that are adopted in extracting metals from their ores may conveniently be grouped in the following manner:—

The thick, black Roman numerals refer to the Thermal Equations, Chapter XI.

## A. DRY PROCESSES.

I. *a. By Simple Fusion with Suitable Fluxes.*

(a) In blast or reverberatory furnaces.	1. Gold . . .	} This process is only applicable to metals in an uncombined form.
	2. Silver . . .	
	3. Platinum . . .	
	4. Copper . . .	
(b) In tube-furnace.	5. Bismuth . . .	By liquation.

*β. By Simple Heating.*

(a) In kilns or reverberatories.	1. Mercury (I.) . . .	From its sulphide, the presence of air being necessary.
(b) In retorts.	2. Arsenic . . .	From sulphides of arsenic and iron, air excluded, always with appliances for condensing the volatilised metal.

II. *By Reduction of Oxide by Carbon.*

(a) In blast-furnaces or, more rarely, in hearths or crucibles.	1. Copper (II.) . . .	} Usually after previous roasting of sulphide or arsenide;
	2. Lead (III.) . . .	
	3. Antimony (IV.) . . .	
	4. Nickel . . .	
(b) In reverberatory furnace.	5. Iron (V.) . . .	} Usually with simultaneous carburisation of the liberated metal.
	6. Nickel . . .	
	7. Manganese . . .	
	8. Tin.	
	9. Bismuth.	