Spain, possibly even in England, and it seems improbable that it should have been lost in that archipelago, where the traditions of ancient civilization must have been better preserved than in almost any other place. In 523 Cassiodorus writes of the "innumerosa navigia" belonging to Venice, and where trade is active there is always a probability that manufactures will flourish. However this may be, the earliest positive evidence of the existence at Venice of a worker in glass would seem to be the mention of Petrus Flavianus, phiolarius, in the ducale of Vitale Falier in the year 1090. In 1224 twenty-nine persons are mentioned as friolari (*i.e.*, phiolari), and in the same century "mariegole" or codes of trade regulations were drawn up (*Monografia della Vetraria Veneziana e Muranese*, p. 219). The manufacture had then no doubt attained considerable proportions; in 1268 the glass-workers exhibited decanters, scent-bottles, and the like; in 1279 they made, among other things, weights and measures. In the latter part of this century the glass-houses were almost entirely transferred to Murano. From thenceforward the manufacture continued to grow in importance; glass vessels were made in large quantities, as well as glass for windows. The earliest example which has as yet been described—a cup of blue glass, enamelled and gilt—is, however, not earlier than about 1440. A good many other examples have been preserved which may be assigned to the same century: the earlier of these bear a resemblance in form to the vessels of silver made in the west of Europe; in the later an imitation of classical forms becomes apparent. Enamel and gilding were freely used, in imitation no doubt of the much admired vessels brought from Damascus or Egypt. Many of the ornamental processes which we admire in Venetian glass were already in use or were invented in this century, as that of mille fiori, in which rods of various colours are joined by heat and so arranged as when cut transversely to form patterns resembling flowers or coral-lines. Such sections were then placed side by side and united by a lining of heated glass applied to them; the joint mass was then reheated and worked into the desired form. The beautiful kind of glass known as vitro di trina or lace glass, was made by a variation of the same process; the rods or canes, being composed of opaque white threads surrounded by transparent glass, were placed side by side in a mould, and a bubble of glass blown into the midst so as to adhere to the canes; the whole was then reheated and fashioned in the same manner as any ordinary glass. Sometimes two canes or cylinders were used, the lines of which ran in opposite directions, and a reticulated pattern was thus produced. An elaborate account of the process is given by M. Labarte (*Histoire des Arts Industriels*, iv. 575 *sq.*). Many of the examples of this process exhibit surprising skill and taste, and are among the most beautiful objects produced at the Venetian furnaces. Glass was made by the Romans in like manner, but no ancient example which has come down to us equals in correct execution some of those made at Venice. That peculiar kind of glass usually called schmelz, an imperfect imitation of calcedony, was also made at Venice in the 15th century. Avanturine glass, that in which numerous small particles of oxide of copper are diffused through a transparent yellowish or brownish mass, was not invented until about 1600.

The peculiar merits of the Venetian manufacture are the elegance of form and the surprising lightness and thinness of the substance of the vessels produced. The glass on the other hand wants brilliancy, and is often tinged with yellow, or if, as is not uncommon, too much manganese (which neutralizes the yellow tinge imparted by the presence of iron) has been used, a faint purple. This slight coloration may not, however, appear a defect to eyes fatigued by the brilliancy of modern flint glass. The Venetian workmen perhaps somewhat abused their skill by giving extravagant forms to vessels, making drinking glasses in the forms of ships, lions, birds, whales, and the like.

Besides the making of vessels of all kinds the factories of Murano had for a long period almost an entire monopoly of two other branches of the art,—the making of mirrors and of beads. Attempts to make mirrors of glass were made as early as 1317 A.D., but even in the 16th century mirrors of steel were still in use. To make a really good mirror of glass two things are required,—a plate free from bubbles and striæ, and a method of applying a film of metal with a uniform bright surface free from defects. The principle of applying metallic films to glass seems to have been known to the Romans and even to the Egyptians, and is mentioned by Alexander Neckam in the 12th century, but it would appear that it was not until the 16th century that the process of "silvering" mirrors by the use of an amalgam of tin and mercury had been perfected. During the 16th and 17th centuries Venice exported a prodigious quantity of mirrors, but France and England gradually acquired knowledge and skill in the art, and in 1772 only one glass-house at Murano continued to make mirrors.

The making of beads was probably practised at Venice from a very early period, but the earliest documentary evidence bearing on the subject does not appear to be of earlier date than the 14th century, when prohibitions were directed against those who made of glass such objects as were usually made of crystal or other hard stones. In the 16th century it had become a trade of great importance, and about 1764 twenty-two furnaces were employed in the production of beads. Towards the end of the same century from 600 to 1000 workmen were, it is stated, employed on one branch of the art, that of ornamenting beads by the help of the blow-pipe. A very great variety of patterns was produced; a tariff of the year 1800 contains an enumeration of 562 species and a vast number of sub-species. Beads to the value of £200,000 are still annually made in Venice (*Monografia della Vetraria Veneziana e Muranese*).

The efforts made in France, Germany, and England, in the 17th and 18th centuries, to improve the manufacture of glass in those countries had a very injurious effect on the industry of Murano. The invention of flint glass in England (about 1620?) brought in its train the practice of cutting glass, a method of ornamentation for which Venetian glass from its thinness was ill-adapted. One remarkable man, Giuseppe Briati, exerted himself, with much success, both in working in the old Venetian method and also in imitating the new fashions invented in Bohemia. He was especially successful in making vases and circular dishes of "vitro di trina," one of the latter in the Correr collection at Venice, believed to have been made in his glass-house, measures 55 centimetres (nearly 23 inches) in diameter. The vases made by him are as elegant in form as the best of the Cinquecento period, but may perhaps be distinguished by the superior purity and brilliancy of the glass. He also made with great taste and skill large lustres and mirrors with frames of glass ornamented either in intaglio or with foliage of various colours. He obtained a knowledge of the methods of working practised in Bohemia by disguising himself as a porter, and thus worked for three years in a Bohemian glass-house. In 1736 he obtained a patent at Venice to manufacture glass in the Bohemian manner. He died in 1772.

The fall of the republic was accompanied by interruption of trade and decay of manufacture, and in the last years of the 18th and beginning of the 19th century the glass-making of Murano was at a very low ebb. In the year 1838 Signor Bussolin revived several of the ancient processes of glass-working, and this revival was carried on by C. Pietro Biguglia in 1845, and by others, and later by Salviati, to whose successful efforts the modern renaissance of the glories

of Venetian art glass is principally due. Salviati revived the former processes and practised them, not in mere slavish imitation, but with freedom, invention, and fine artistic instinct. Every general industrial exhibition has contained brilliant examples of the products of the Venice and Murano Glass Company, composed chiefly of English capitalists, and formerly managed by Salviati.

The fame of Venice in glass-making so completely eclipsed that of Italian cities that it is difficult to learn much respecting their progress in the art. It appears, however, that as early as 1295 furnaces had been established at Treviso, Vicenza, Padua, Mantua, Ferrara, Ravenna, and Bologna. In 1634 there were in Rome two and in Florence one glass-house; but whether any of these produced ornamental vessels, or only articles of common use and window glass, would not appear to have as yet been ascertained.

Western Europe during Roman period.

The history of glass-making in France, Spain, Germany, and England offers many points of resemblance. In the first three, and probably in England also, glass was made at the period of the Roman empire; in France about Lyons, as is shown by a monument in the Musée Lapidaire to one Julius Alexander, described as an "opifex artis vitriæ," in Normandy and Poitou, and probably in many other parts. In Spain glass, according to Pliny, was manufactured (*Nat. Hist.*, xxxvi. 26, 66) in many parts of the country, "per Hispanias," but the remains of Roman glass-making have been chiefly found in the valleys which run down to the coast of Catalonia, but also near the mouth of the Ebro, in Valencia and in Murcia (Señor Rico y Sinobus, *Del Vidrio*, p. 11).

Glass-making in Germany during the Roman period would seem to have been carried on extensively at Cologne, near which city many remarkable glass vessels of peculiar character have been discovered. The art was probably not lost during the period which followed the downfall of the Roman power. In the year 758 Cuthbert, abbot of Jarrow, wrote to Lullo, bishop of Mainz, to request him to send him a maker of glass vessels. It is scarcely probable that the art had been forgotten and revived between the 5th and the 8th centuries.

It is not equally clear that glass was made in England, though it is probable that this was the case. Both vessels and window glass have been found in almost all parts of the country, and at Buckholt, near the Roman road from Winchester to Salisbury, the remains of a glass furnace, among which were numerous fragments of glass which may possibly have been of Roman origin, and a fragment of undoubtedly Roman pottery. But associated with these were fragments of glass of the 14th and later dates, and of pottery of the 16th century.

The dark ages.

Very little has been ascertained as to the practice of the art in either of the four countries during the dark ages, but it would seem to have been preserved in France and Germany, and perhaps also in England and Spain. The fact narrated by Bede, in his history of the abbots of Wearmouth, that Benedict Biscop about 675 procured workmen from France to make glass for his monastery, shows at once that it was preserved in France and lost or nearly so in England. But a great quantity of drinking vessels are found in the tombs of the Anglo-Saxons while still pagan; and although the like are found both in France and in Germany, it is said that a greater number and more varieties occur in England, and it has thence been inferred that they were probably made in the country. Welsh poets of the 6th century (?), Aneurin and Llywarch Hen, both mention glass vessels by a name, "wydr," evidently derived from vitrum, and it is possible that the Welsh retained a knowledge of its manufacture. Some knowledge of the art of manipulating glass existed in Ireland in and before the 12th century, as is shown by cameo heads and small pieces of mosaic glass of quite peculiar patterns which occur on objects of Irish workmanship (*Transactions of the Royal Irish Academy*, vol. xxiv., Antiq., part. iv.).

In France "vitrarii" are mentioned in several centuries from the 6th to the 11th; in Germany, as has been shown above, there is ground for believing that the art was practised in the 8th century; and in the 12th artisans are found at Cologne with the designation "ustor" attached to their names, which Merlo (*Künst und Künstler in Köln*, p. 563) suggests may probably mean maker of glass. Nothing seems to have been ascertained about the existence of the art in Spain between the Gothic conquest and the 13th century, when it was practised at Almeria by the Moors.

During the mediæval period France produced large quantities of glass, as well in the form of vessels as in that of window glass. The first were made on a large scale in Dauphiné in the 14th century. In 1338 Humbert the dauphin granted a part of the forest of Chamborant to a glass-maker on condition that he should furnish him with more than 3000 vessels of glass annually (*Hist. Dalph.*, ii. 363). In 1302 window glass was made at Bezu le Foret, in the department of the Eure, for the king of France; a fragment of a roll of accounts for that year is preserved in the Bibliothèque Nationale. Glass was also made in Poitou, and a drageoir with the arms of Charles VIII. of France (1470–1498) has been engraved by M. Fillon (*L'art de Terre*, &c.) which is believed to have been made in that province.

Much glass was no doubt made for windows both in Germany and the Low Countries, during the Middle Ages, and in 1453 mention occurs of a fountain and four plateaux made for Philip the Good, duke of Burgundy, by a glass-maker of Lille; but if artistic objects were made, hardly any examples have been preserved. Glass-makers existed at Vienna in 1221 (Peligot, *Le Verre*, p. 342). In 1428 a Muranese artificer set up a furnace in the same city, and another was established by another Italian in 1486, which it is said was still at work in 1563. How far these efforts to rival the manufactures of Murano may have succeeded we have no information, but contemporaneously the native artificers continued to produce articles for common use, as we may see by the woodcut in the edition of George Agricola *De Re Metallica*, published at Basel in 1561, representing the interior of a glass-house. In this the tall cylindrical drinking-glasses known as wiederkoms, bottles with big bellies and slender necks, and retorts may be seen. A glass-house was founded at Daubitz in Bohemia in 1442, others in 1504 (Peligot, *Le Verre*, p. 343).

In England vessels of glass seem to have been but little used during the Middle Ages; they occur very rarely in inventories, and when they do, as in the Calendars of the Treasury of the Exchequer, they are usually described as mounted in gold or silver, or as painted, being probably enamelled glass vessels from Constantinople, Damascus, or Venice, objects rather of virtu than of daily use. It has even been asserted that there is no evidence that any description of glass was made in England before the 15th century, but in the roll of the taxation made at Colchester in 1295 three of the principal inhabitants are designated "verrer"; and it would seem hardly probable that so many in such a town were glaziers only and not glassmakers. In the 14th century Andrew le glasswright is mentioned in the records of Great Yarmouth. In 1439 (or 1447) English glass is mentioned in the contract for the windows of the Beauchamp chapel at Warwick, but disparagingly, as the contractor binds himself not to use it. In 1485, however, it is mentioned in such a manner as to lead to the conclusion that it was dearer and presumably better than either "Dutch, Venice, or Normandy glass"

(*Domestic Architecture of the Middle Ages*, by Hudson Turner, p. 78).

In Spain glass was made at Barcelona in considerable quantities in 1324; and Almeria, according to an Arab author of the 13th century, was famous for its manufacture of glass. In the 15th century the export of glass from Barcelona was considerable; Jeronimo Paulo in 1491 says that glass vessels of various sorts were sent thence to many places and even to Rome.

In the 16th century the fashion of using glass vessels of ornamental character spread from Italy into France, England, and the Low Countries. Henry VIII. had a large quantity, chiefly or wholly, it would seem, of Venetian manufacture (see inventory in 1542, *Archæological Journal*, vol. xviii.). This increasing use of glass led to the reflexion that large sums of money went annually to Venice for such wares, and to the question whether the manufacture might not be carried on at home. We therefore find that about the middle of this century attempts were made to introduce the Venetian methods of manufacture into the several countries; Henry II. of France established an Italian named Mutio at St Germain-en-Laye, and Henry IV. in 1598 permitted two "gentilshommes verriers" from Mantua to settle themselves at Rouen in order to make "verres de cristal et autres ouvrages qui se font à Venise." A like attempt was made in England about 1550, for in that year eight glass-makers from Murano addressed from London a petition to the Council of Ten at Venice praying to be excused from the penalties decreed by that body in 1549 against Venetian subjects who taught the art to foreigners (*Cal. State Papers*, Venetian, No. 648). The council allowed the eight workmen to remain until the end of the term for which they had engaged themselves. Other attempts followed: Stow says (*Chron.*, p. 1040) that Venice glasses were first made in London by one Jacob Vessaline about the beginning of the reign of Queen Elizabeth, and in 1565 one Cornelius de Lannoy (or Launoy) was working in the pay of the Government (*Cal. State Papers*, Dom.). Others, as Carre or Quarre, and Becku *alias* Dolin, from the Low Countries, were engaged in similar undertakings during the latter part of this century, but it does not seem that any great success was attained, as the importation of glass from Venice continued until long after.

These attempts to rival Murano seem to have been most successful in the Low Countries and in Spain. Ambrozio de Mongarda had a privilege in the former country to make "voirres de cristal à la faschon de Venise," which in 1599 was continued to Philippe de Gridolphi; his glass-house was at Antwerp. Glass-works also existed at Liége. Much glass in the 16th century was sent from Antwerp to England (Houdoy, *Les Verreries à la façon de Venise*). This manufacture went on during the following century, and many examples remain, more or less resembling the products of Murano.

In Germany Ferdinand I. established a glass-house at Weidlingen near Vienna, which was to work in the Italian manner; but no great success it would seem attended these efforts, partly no doubt because about the same time the native glass-makers struck out a new and original style of ornamentation for the great cylindrical beakers, sometimes 20 inches in height, usually called wiederkom (come again), but which M. Peligot says ought to be called willkomm (welcome). This was a somewhat coarse but very effective system of painting in enamel such subjects as the emperor and electors of Germany, or the imperial eagle bearing on its wings the arms of the states which composed the empire, &c. The earliest example which has been met with bears the date 1553, but the system had great vogue, and continued in use until about 1725.

Spanish writers have not as yet acquainted us with the precise means by which the Venetian methods of working were brought to their country; but Gaspar Baneiros in his *Chronographia*, published in 1562, says that the glass made at Barcelona was almost equal to that of Venice, and during this and the next century large quantities were exported. Venetian glass was imitated in several other places in Spain, and with considerable success, as several examples in the South Kensington Museum testify. The native forms and methods of working, however, went on contemporaneously, and it would appear do so down to the present day.

The branch of glass-making in which the greatest results were obtained in France during the 17th century was that of the manufacture of mirrors. In 1665 the services of eighteen Venetians were obtained, and a factory established in the Faubourg St Antoine at Paris, and another factory was founded at Tour-la-Ville near Cherbourg. These were united and worked with great success; the plates which ornament the "Galerie des Glaces" at Versailles were made at Tour-la-Ville. In 1688 the process of casting plates of glass was first adopted in modern times (for the window glass of Roman times was cast); and thus it became possible to make mirrors of dimensions which could not be attained as long as the plates were produced by blowing. The manufacture was carried on at St Gobain, still the seat of an immense production of glass.

English glass-making of the 17th century is distinguished by one of the most important innovations in the practice of the art which has at any time been introduced, that of using a large proportion of oxide of lead in combination with potash. Glass so made is more brilliant than other kinds, and is known in England as "flint glass," in France as "cristal." The employment of lead as one of the ingredients of glass was not a discovery, for it had been practised to a small extent and for certain purposes, as in the imitation of gems by the Romans, and through the Middle Ages. Neither the date when flint glass was first made nor the inventor of the process is known.

Sir William Slingsby before 1611 (*Cal. State Papers*, Dom.) had obtained a patent for making glass with sea coal; and in 1615 the use of wood for that purpose was forbidden by royal proclamation. How far this proclamation may have been obeyed does not appear, but Sir R. Mansel, who held a patent of monopoly for glass-making from 1616 until about 1634 (and perhaps even later), states in 1623 that furnaces erected in London, the isle of Purbeck, Milford Haven, and on the Trent, had all failed, but that he had established them successfully at Newcastle-on-Tyne. Probably coal was used at this last place, and it seems not unlikely that flint glass may have been first made there. Merret, however, writing about 1665 (in his edition of the *Ars Vitraria* of Neri), says that glass made with lead was not in use in the English glass-houses on account of its too great fragility; but in 1673 Evelyn notes in his diary a visit to the Italian glass-houses at Greenwich "where glass was blown of finer metal than that of Murano," and in 1677 a visit to the duke of Buckingham's glass-works (at Lambeth), "where they made huge vases of metal as clear, ponderous, and thick as crystal, also looking-glasses far larger and better than any that come from Venice." From this time much glass was made in England, and Dr Pococke, who travelled in Germany in 1736, gives the preference in point of quality to English glass over Bohemian.

During this century much art and labour were employed in Germany in the ornamentation of vessels for drinking, such as goblets and wiederkoms. Sometimes they were painted in grisaille, the subjects being battles, processions, and the like, sometimes engraved or etched; common subjects are escutcheons with arms, views of cities, ciphers, &c. Many excellent artists worked in these various styles (Beckmann, *Hist. of Inventions*, iii. 209; Doppelmayr, *Nürnbergische Künstler*, p. 231, 233, &c.), and their works brought high prices. Dr Pococke mentions seeing some at Rispen, to which the glass-works formerly carried on at Potsdam had been removed, which cost from £100 to £150. Excellent material for these artistic efforts was furnished by the Bohemian furnaces; the art was patronized by several German princes; the celebrated Kunkel was in 1679 director of the glass-houses at Potsdam, which were carried on at the cost of the elector, and where the beautiful ruby glass was produced. Etching and engraving on glass was also much practised in Holland.

In Spain glass was made in 1680, at San Martin de Valdeiglesias, in imitation of Venetian; and Barcelona, Valdemaquada, and Villafranca are named in a royal schedule of the same date, fixing the prices at which glass was to be sold in Madrid, as places where wares imitative of Venetian were made. There was also an important manufactory at La Granja (see Introduction to *Cat. of Spanish Glass in South Kensington Museum*, by Señor Riano). Some of the products of the Spanish furnaces closely resemble those of Murano, but rarely exhibit much beauty or much originality. Others again, attributed to the factory of San Ildefonso and to the 18th century, bear a very close resemblance to some of the Dutch glass of that period.

Although during the 18th and earlier part of the 19th century progress was made both in the purity and in the beauty of the material (especially in the case of glass for optical purposes), and in the organization and working of factories, it was a period marked in no country by novelty or of artistic effort in the manufacture of glass. M. Labarte even goes so far as to say (*Hist. des Arts Industriels*, iv. 597) that in France in 1759 the fabrication of "vases de verre" had so completely fallen into decadence that the Academy of Sciences offered a prize for an essay on the means by which the industry could be revived. In the beginning of the present century cut glass was much in vogue, and was produced in England of great brilliancy, though the forms of the objects often left much to be desired in point of elegance.

The manufacture of coloured glass for windows was a consequence of the revival of Pointed architecture, and England, France, Belgium, and Germany have in this century rivalled each other in its production.

The Exhibition of 1851 did not perhaps produce a more marked effect on any of the industrial arts than on that of glass. The progress made since that date in the fabrication of artistic glass wares (the verrerie de luxe of the French) has been surprising, and at the present moment enlightened and enterprising manufacturers of glass are in every country studying the products of the furnaces of all times and all countries, as their predecessors at Murano in that great period of the art—that of the Renaissance—did the relics of Roman glass-working (Biringuccio, *Pirotechnia*, lib. ii.) in order to glean from them lessons and suggestions of further advance in their art. (A. NE.)

The Manufacture of Glass.

Glass, in its ordinary signification, is a brittle, transparent compound produced by the fusion, at a very high temperature, of silica (silicic acid) with one or more basic substances, one of which, in all cases, must be an alkaline metal. But the silicates of sodium and potassium, whether separate or combined, being soluble in water, and also readily acted on by other agents, are not in themselves suitable for most of the purposes to which glass is ordinarily applied. When, however, to these silicates, or to either of them, a silicate of an alkaline earth is added, the resulting body is not sensibly affected by water or ordinary solvents; and it is the fused amorphous mass thereby obtained that alone is glass in the restricted technical sense. Thus the definition given by Dumas that glass is a silicate of at least two metals belonging to different groups, one of which must be an alkaline metal, strictly embraces and limits all varieties of ordinary glass. Boracic acid, a substance closely allied in chemical properties to silica, has a similar influence on the alkalies and alkaline earths, producing by their mutual fusion a transparent amorphous compound; and indeed, for certain special purposes, a glass in which borates to a certain extent supplant silicates is used for optical purposes. The substances, however, which form the essential basis of all varieties of common glass are (1) silica as the acid element; (2) soda or potash as the alkaline base; and (3) lime and oxide of lead as the alkaline earths. To the alkaline earths commercially employed there ought also to be added baryta and alumina, the former being used in the place of lead, and the latter being a common ingredient in certain kinds of glass.

The following tabular statement shows the bodies capable of yielding transparent glass:—

Acid	Alkaline.	Earthy.	
		Colourless.	Coloured.
Silica. Boracic acid.	Oxides of Potassium. Sodium.	Oxides of Calcium. Lead. Barium. Strontium. Magnesium. Aluminium. Zinc. Thallium.	Oxides of Iron. Manganese. Copper. Chromium. Uranium. Cobalt. Gold.

Various authorities who have investigated the constitution of glass have endeavoured to establish a chemical formula for what they term normal glass. The results arrived at, however, by different investigators disagree among themselves; and the balance of opinion is in favour of the view that no such substance as normal glass exists, and that glass does not result from any definite chemical compounds, but is simply a mixture of silicates, with usually an excess of uncombined silica. The proportions in which the ingredients of glass are present, however, have not only a very great influence on the fusibility of the mass; but these conditions also very materially affect the qualities of the substance. In general the more nearly the proportion of silica approaches the amount necessary to form definite compounds with the basic ingredients, the better and the more stable is the quality of the glass. The conclusion of Otto Schott in his investigation of the constitution of glass, that the simplest formula for glass is represented by $\left.\begin{matrix} x\mathrm{Na_2O} \\ y\mathrm{CaO} \end{matrix}\right\} z\mathrm{SiO_2}$, may be accepted as a safe statement.

The phenomenon of devitrification, which is exhibited most readily by glass of inferior quality, has important bearings on the chemical constitution of glass, as well as on the working of the material. Devitrification is a change which may be induced in all varieties, but only with difficulty in the finer kinds of potash glass—either by slowly cooling the glass from the state of fusion, or by heating it in a mixture of sand and plaster of Paris till it softens, and then allowing it to cool by very slow degrees. Thereby it partly or entirely loses its transparent amorphous form, and by the formation of innumerable minute crystals it becomes opaque. When such a change penetrates the entire mass it assumes a milky and porcelain-like appearance, whence it is in this condition known as Réaumur's porcelain—the phenomenon having been first investigated by that observer. Devitrification renders the material much harder and less fusible than the same glass in a transparent