1 Commercial Nitrogen Production

Ammonia is used in the production of a variety of commercially important products such as agricultural fertilizer (70-80% of use), plastics, explosives and synthetic fibre [1]. Production is positively correlated with increases in standard of living and population growth. As 96% [2]of global ammonia production uses the energy-intensive Haber-Bosch process, in an era where governments worldwide are pursuing net-zero emissions alternative approaches may have to be found to simultaneously satisfy government policy and market demand. Countries which are net exporters of agricultural products are the heaviest consumers per capita. In 2018, global annual consumption was 18kg per capita and is projected to grow to 21kg per capita by 2050. The flatness of the projected global per capita annual consumption rate is likely due to a complex set of factors such that saturation of use in developed economies, improvements in efficiency of use, regulatory constraints and reductions in use in some industries. By country, the largest producers of ammonia are China (44Mt/yr, 2015), India (12Mt/yr), Russia (10Mt/yr) and the United States (95Mt/yr) who collectively account for about 75% of the total worldwide production [3].

1.1 Primary North American Producers

As a mature industrial process requiring large capital investment in plant infrastructure, it is not surprising that the bulk of large producers are chemical conglomerates, although there are smaller players that satisfy regional demand. To name a few companies that has substantial interests in ammonia production[4]:CF industries (CF NYSE), Chevron Phillips (CVX), Koch Industries (private), LSB Industries (LSB NYSE), CVR energy (CVR) , Mosaic (MOS NYSE), Green Valley Chemical (private), Iowa Fertilizer (OCI, Netherlands).

Startups and industrial behemoths are also directing focus to the so-called "green" ammonia market, where innovative though economically unproven production techniques are used to reduce carbon footprint. For example, CF industries is building a 0.02Mt/yr green ammonia plant at its established nitrogen complex in Donaldsville which currently has the capacity to produce 4Mt/yr.

1.2 Haber-Bosch Process

The modern HB process commonly uses hydrogen produced from gasification of fossil fuels, primarily natural gas. Air is the source of nitrogen. The catalytic reaction converting hydrogen and nitrogen to ammonia requires high pressures and moderately high temperature to effeciently complete.

1.3 History [5]

The genesis of the process lay in the realization that at the early years of the 20th century, natural sources of nitrates (bird and bat guano deposits occuring on tropical islands and natural nitrate deposits) would be insufficient to meet future industrial and agricultural demand. The famous German scientist Fritz Haber developed by 1909 a demonstration laboratory-scale high pressure plant and catalysts whose rights were sold

to the BASF conglomerate. Carl Bosch, an industrial chemist (who went on to co-found IG Farben in 1925) built out industrial-scale 20000 T/yr plant that began operation in 1913, just in time to meet German demand for munition and explosives production for World War I.

Many of the innovations subsequently focused on process optimization and on improvements in safety, efficiency and cost of catalysts that drive the chemical reaction. The metal osmium was first used, followed by uranium, although in 1909 Alwin Mittasch discovered an iron-catalyst that is still used today.

References

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