STUDY ON ZERO FLARE POLICY FOR OIL AND GAS EXPLORATION AND PRODUCTION INDUSTRY IN INDONESIA

By
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ABSTRACT

Flaring is an essential practice in oil and gas production, primarily for safety reasons. Although data indicate that, on a worldwide basis, gas flaring contributes only 1% of anthropogenic carbon dioxide emissions, for environmental and resource conservation reasons, flaring should always be minimized as much as practicable.

In the frame work of Global Gas Flaring Reduction Public-Private Partnership (GGFR), Government of Indonesia (GOI) through Directorate General of Oil and Gas is preparing a draft policy for Green Oil and Gas Industry Initiative (GOGII). GOI encourage oil and gas activity in Indonesia to be environmental friendly industries by implementing Zero Flare, Zero Discharge, Clean Air and Go Renewable programs. Zero flare can be achieved by different kind of methods, such as re-injection of associated gas, gas utilization on-site, and collection and market to downstream markets.

This paper tries to review and evaluate the possibility of implementing the zero flare policy for oil and gas exploration and production industries in Indonesia, in the frame work of contributing to GOI in preparing draft policy for GOGII.

Key words: environmental, gas flaring, zero flare and re-injection.

I. INTRODUCTION

The option to release gas to the atmosphere by flaring is an essential practice in oil and gas production, primarily for safety reasons. Flaring is the controlled burning of natural gas produced in association with oil in the course of routine oil and gas production operations. The availability of a flare ensures that associated natural gas can be safely disposed of in emergency and shutdown situations. Where gas cannot be stored or used commercially, the risk of fire and explosion must be reduced by flaring.

It is in an oil company's interest to minimize the amount of gas flared in order to realize as much value as possible from the hydrocarbons being produced. A variety of mechanisms may potentially be used to minimize flaring. However, it may not be technically or economically feasible to sell some or all of the gas, for reasons that are often a combination of geography, availability of customers, and government energy policies. Similarly, it may not be technically or economically feasible to re-inject the gas into underground reservoirs. Therefore, gas may have to be flared as a waste product. In some cases, venting may be preferable to flaring, depending on considerations such as local noise impacts, toxicity of gases being produced, and hydrocarbon content of the gas.

Available data indicate that, on a worldwide basis, gas flaring contributes only 1% of anthropogenic carbon dioxide emissions (cf. Figure 1)[1]. Nevertheless, for environmental and resource conservation reasons, flaring should always be minimized as much as practicable, consistent with safety considerations. Flaring can have local environmental impacts, as well as producing emissions which have the potential to contribute to global warming.

Government of Indonesia (GOI) through Directorate General of Oil and Gas is preparing a draft policy for Green Oil and Gas Industry Initiative
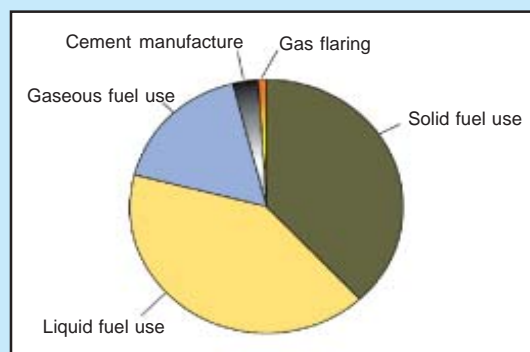
Figure 1
Contributions to anthropogenic carbon dioxide

(GOGII). GOI encourage oil and gas activity in Indonesia to be environmental friendly industries by implementing Zero Flare, Zero Discharge, Clean Air and Go Renewable programs.

An example of the zero flare policy that has been implemented is at the Mubarraz, Abudabi. All of the gases that were in the past burned off in the flare are now re-injected into the underground oil reservoir by a large compressor. This "Zero Flare" system, which emits no sulfur oxides or CO_2, was in operation as of May 2001. The completion of this project helps to prevent air pollution in the Emirate of Abu Dhabi, and at the same time eliminates 200,000 tons of greenhouse gas emissions (CO_2 equivalent) annually.

Zero flare policy does not mean only by zero discharge at all, such as that has been implemented at Mubarraz, Abudabi. Zero flare policy as a part of Global Gas Flaring Reduction (GGFR) could also be implemented through small-scale utilization of flared gas by making more gas (and gas-fired power) available for use by the rural and urban settlement surrounding the oil and gas fields. It is also intended to reduce the environmental and health impact of gas flaring to the public settlements.

The authors try to review and evaluate the possibility of implementing the zero flare policy for oil and gas exploration and production industries in Indonesia, in the frame work of contributing to GOI in preparing draft policy for GOGII.

II. GAS FLARING REDUCTION POLICY

The World Bank estimates that the annual volume of natural gas being flared and vented is over 100 bn cm, enough to provide the combined annual gas consumption of Italy and France. Flaring in Africa alone could produce 200 TWh of electricity, about 50% of the current power consumption of the African continent and more than twice the level of power consumption in Sub-Saharan Africa (excluding South Africa). This is also equivalent to more than 10 % of committed emission reductions by developed countries under the Kyoto Protocol for the period 2008-2012. About 75% of global venting and flaring occurs in 10 countries, with the next 10 countries adding another 15%[2].

In 2001, the Global Initiative on Natural Gas Flaring Reduction was initiated by the government of Norway and the World Bank Group to investigate the issue. It found that for the past 20 years, global flaring levels have remained virtually constant (although individual country levels have fluctuated), despite efforts made by individual governments and companies, and despite many successes in reducing flaring.

As a result of its findings, the initiative was transformed into the Global Gas Flaring Reduction Public-Private Partnership (GGFR) at the World Summit on Sustainable Development in 2002 in Johannesburg, to address the issue through collaboration. In addition to the World Bank Group, this public-private partnership currently includes BP, Chevron, ENI, ExxonMobil, Norsk Hydro, Royal Dutch Shell, Statoil, and Total and the governments or national oil companies of Algeria, Angola, Cameroon, Canada, Chad, Ecuador, Equatorial Guinea, Indonesia, Nigeria, Norway, The United Kingdom and the United States, with other companies and countries expected to join. The growing membership, now including OPEC, covers over 70% of the sources of venting and flaring globally.

GGFR estimates that global flaring is 150 to 200 bcm or >400 MTCO2e per year, which Major areas are: Russia, Africa and Middle East, while Indonesia contributes around 5 bcm (cf. Figure 2)[3]. Potential Flare Aggregation Projects in Indonesia are depicted in Figure 3[4].

III. GAS FLARING REDUCTION STRATEGY

Flaring is a combustion process used to dispose of natural gases (sweet gas, sour gas, acid gas or other hydrocarbon vapor) through a vertical stack.
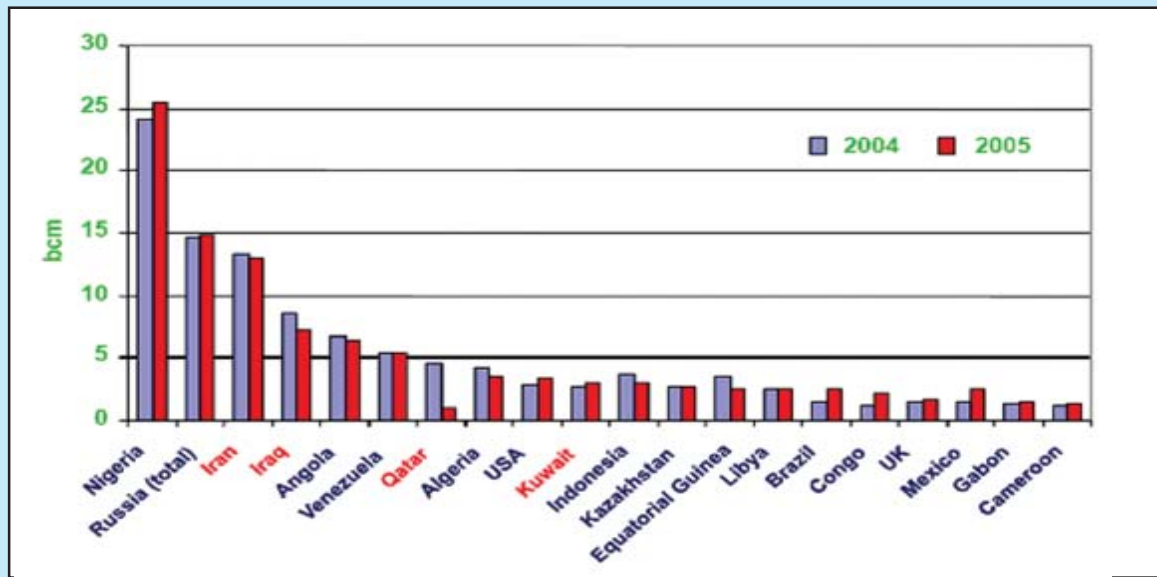
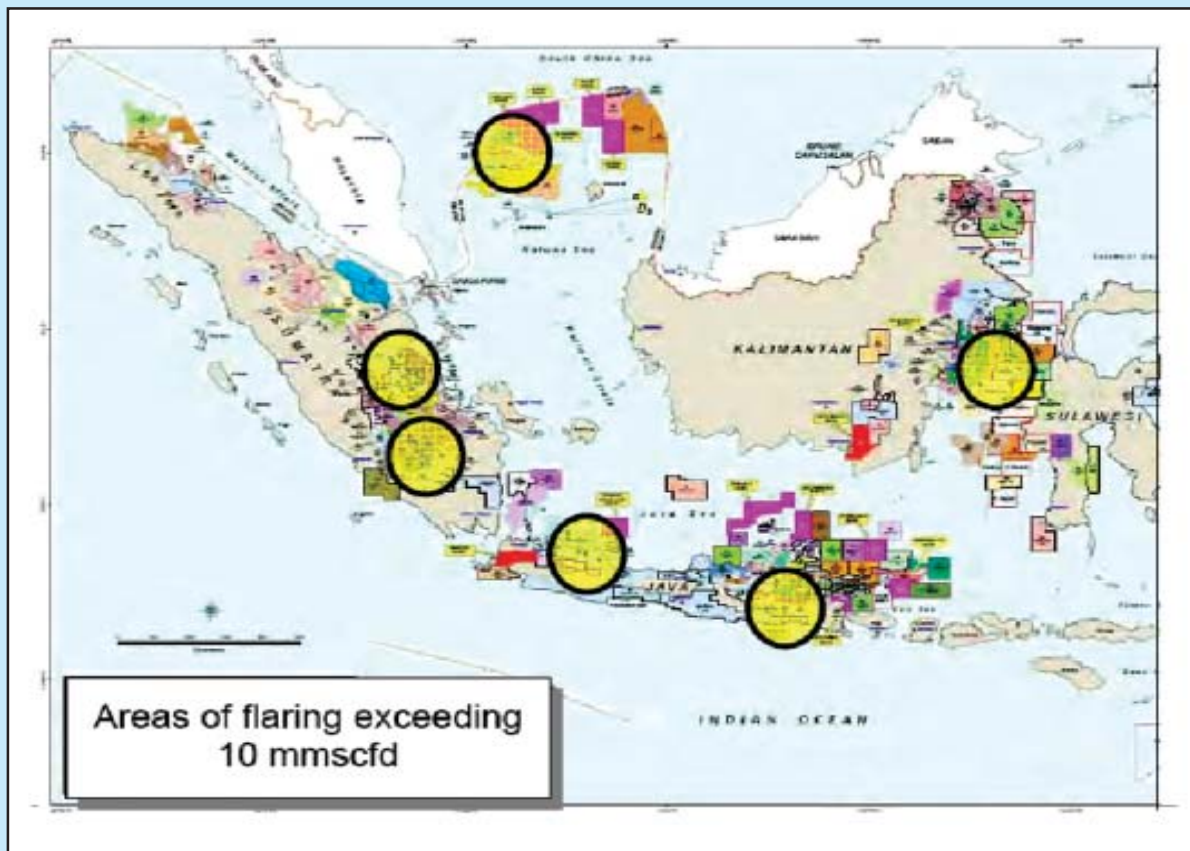**Figure 2**
Global flaring level in 2004 and 2005

Figure 3
Potential Flare Aggregation Projects in Indonesia[3]

Facilities in the oil and gas industry may routinely flare small volumes of natural gas that are technically difficult and uneconomic to conserve. Flaring is also an important safety measure, used to safely dispose of natural gas that would otherwise pose a hazard to workers, nearby residents and facility equipment during non-routine occurrences like emergencies, process upsets, equipment failure and power failure conditions. Flaring is recognized as an important issue for the upstream oil and gas industry for health, safety and environmental impacts, as well as conservation of energy resources.

Flare reduction types of activities include: re-injection of associated gas, gas utilization on-site, and collection and market to downstream markets.

Re-injecting associated gas into certain sub-surface formation may help in reducing green house gases (GHG) which contribute in global warming. Nevertheless, re-injection of this associated gas should be considered as a last choices, since despite of its cost, the safety and environmental problem of re-injection process would be the most difficult to be predicted. Re-injection project, however, may be eligible as Clean Development Mechanism (CDM) under the Kyoto Protocol that represent opportunities for the countries which restrict gas flaring to capture part of the global public benefits of emission reductions.

Gas utilization on-site, and collection and market to downstream markets are other interesting choices in gas faring reduction strategy. To improve the economics of associated gas and create suitable opportunities for operators to use gas rather than flare and vent, GOI could create efficient technical regulations, and also develop competitive downstream markets and transparent and efficient regulatory and legal frameworks that provide access to network and customers. Constraints of gas utilization on-site could be insufficient infrastructure and poor access to local and international energy markets.

Referring to Potential Flare Aggregation Projects in Indonesia as depicted in Figure 3, it is found that in certain populated area, such as East Java, poverty reduction can be implemented as an integral part of the GGFR program. The developing concepts is how local communities close to the flaring sites can use natural gas and liquefied petroleum gas (LPG) that may otherwise be flared and wasted. The program has already been evaluated opportunities for small-scale gas utilization in several countries[5].

IV. ECONOMIC AND ENVIRONMENTAL IMPACT OF GAS FLARING

Gas flaring is associated with the release of a large number of pollutants. Improper combustion, as indicated by smoke from the flare stack, contributes to increasing the hazardous chemicals released into the environment including volatile organic compounds. The substances include [5]:

- More than 250 identified toxins, including carcinogens such as benzopyrene, benzene, carbon disulphide (CS_2), carbonyl sulfide (COS), and toluene
- Metals such as mercury, arsenic, and chromium
- Nitrogen oxides
- Sour gas with H_2S and SO_2

Indeed, such toxic pollutants will certainly give negative impacts to the surroundings including the community health. These conditions, for example, can be found at East Java, where many plants did not grow well due to the gas flare. The conditions will be even worst when gas being flared contains high sulfur resulted from the sour wells.

Most gas flaring reduction is in essence a question of changing the purpose of the combustion at the oil field from gas elimination (flaring) to gas use, (for example, power production), or of moving the combustion away from the field—normally to a load center where it will be combusted for industrial or power production purposes. The local environmental effects of flaring therefore depend on the efficiency and location of the combustion process and which type of fuel is replaced by gas use. Since local effects are project specific, it is recommended that the project must be analyzed on a case-by-case basis.

Economic impacts depend on how government will give financial incentive to the oil industries, opening up of opportunities for private entities to take part in the production and distribution of gas and electricity. These need studies to determine how the projects might best be structured institutionally and commercially, preparation of a detailed gas utilization strategy, additional socioeconomic surveys to deal with pricing, subsidies, and the opportunities to achieve poverty alleviation as well as detailed project design.

V. CONCLUSIONS AND RECOMMENDATIONS

Flaring is an essential practice in oil and gas production, primarily for safety reasons. It is in an oil

company's interest to minimize the amount of gas flared in order to realize as much value as possible from the hydrocarbons being produced. Although available data indicate that, on a worldwide basis, gas flaring contributes only 1% of anthropogenic carbon dioxide emissions, for environmental and resource conservation reasons, flaring should always be minimized as much as practicable. Flaring can have local environmental impacts, as well as producing emissions which have the potential to contribute to global warming.

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Since economic and environmental impacts are local and project specific, it is recommended that the project must be analyzed on a case-by-case basis. These need studies to determine how the projects might best be structured institutionally and commercially, preparation of a detailed gas utilization strategy, additional socioeconomic surveys to deal with pricing, subsidies, and the opportunities to achieve poverty alleviation as well as detailed project design.

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CALCULATION OF NITROGEN HEAT ADSORPTION ON VARIOUS CATALYSTS USING BET-CONSTANT (BET-*C*) DATA

By

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ABSTRACT

BET-C (Brunauer-Emmett-Teller-Constant) was used to calculate the heat of adsorption (ΔH_{ads}) of nitrogen gas on the various catalysts. The well-known Brunauer–Emmett–Teller (B.E.T.) equation is used primarily to determine the surface area from the physical adsorption of a gas on a solid surface. Surface area of catalysts was determined by using surface area analyzer (NOVA 1000).

The BET-C included in the data is usually neglected or is not taken into account. However, by using the basic principles of the adsorption theory fitted with the functions based on the BET adsorption model, the important data of BET-C can be shown in this study. The value of the ΔH_{ads} (N_2) for zeolite, H-zeolite, Pt/zeolite, Pt-Pd/zeolite, and Pt-Ce/zeolite calculated from the equation derived from BET-C are -6.43, -6.52, -8.78, -8.69, -9.71 and -9.52 kJ/mol, respectively.

Key words: BET, adsorption, catalyst, surface area

I. INTRODUCTION

Gas adsorption is practical consequence to chemists in many ways. The phenomenon of surface adsorption has been used to modify the rates of product yields of chemical reactions through heterogeneous catalysis[1]. A good performance catalyst have a large surface area, bind the reactants quickly and effectively, stabilize the activated complex, and release the products of the reaction[2]. Thus, the attraction of various molecules on the surface is extremely important properties of potential catalytic materials. This study will investigate the adsorption of N_2 at cryogenic temperatures on several catalysts and a high area support such as zeolite. The BET-*C* information will be used to estimate the heat of adsorption of N_2 gas. Most methods are based on the isothermal adsorption of nitrogen. Either a single point or multipoint, adsorption method is used to calculate the surface area. BET equation is then used to calculate the total surface area. It is also used as a quality control during catalyst performance testing[3,4]. These attributes are measured by the use of nitrogen adsorption/desorption isotherms at liquid nitrogen temperature and relative pressures (P/Po) ranging from 0.05-1.0. The large uptake of nitrogen at low P/Po indicates of filling of the micropores (< 20 Angstrom) in the catalyst. The linear portion of the curve represents multilayer adsorption of nitrogen on the surface of the catalyst, and the concave upward portion of the curve represents of filling of mesopores (20 - 500 Angstrom) and macro pores (>500 Angstrom). An entire isotherm is needed to calculate the pore size distribution of the catalyst. However, for a surface area evaluation, data in the relative pressure range of 0.05-0.30 are generally used. Different analyses can be applied to these data to develop specific information. For example, application of the surface area, average pore radius and pore volume provide

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information about of the catalyst quality, whereas, in this study, the BET-C is used to determine the strength of the interaction between adsorbate (nitrogen) and catalysts (zeolite based catalysts).

The interaction of a molecule with a given surface will also be dependent upon the presence of any existing adsorbed species, whether these are surface impurities or simply pre-adsorbed molecules of the same type. The energy of adsorption is *negative*, and since it corresponds to the energy *change* upon adsorption it is better represented as ΔE(ads) or ΔE_{ads} associated with the enthalpy of adsorption, ΔH(ads). There is of course a significant barrier to the reverse, desorption process in the diagram below represents the activation energy for desorption[5] (Figure 1).

Clearly in this particular case, the magnitudes of the energy of adsorption and the activation energy for desorption can also be represented as follows:

$$E_a^{des} = \Delta E \text{ (ads)} \quad \text{or} \quad E_a^{des} \sim -\Delta H \text{ (ads)}$$

A qualitative distinction is usually made between chemisorption and physisorption, in terms of the relative binding strengths and mechanisms. In chemisorption, a strong 'chemical bond' is formed between the adsorbate and the catalysts. In this case, the adsorption energy, E_a, of the adsorbed atom is likely to be a good fraction of the sublimation energy of the substrate, and it could be more [6]. Physisorption is often described as implying that no chemical interaction is present. This can't really be true, because if there were no attractive interaction, then the atom would not stay on the surface for any measurable time and

it would simply bounce back into the vapor. A better distinction is that in physisorption, the energy of interaction is largely due to the van der Waals force [7]. This force is due to fluctuating dipole (and higher order) moments on the interacting adsorbate and substrate, and is present between closed-shell systems. Adsorbate is a substance adhered to a surface (the adsorbent). The quantity of adsorbate present on a surface depends on several factors including: adsorbent type, adsorbate type, size, concentration, temperature and pressure. Some adsorbate is listed in Table 1 and the corresponding cross-sectional area which can be used for determining solid surface area [8].

Surface area of a catalyst can be measured by either a multipoint or single point technique. In either the single point or multipoint method, the isotherm points are transformed with the BET equation:

$$\frac{1}{W[(P_o/P)-1]} = \frac{1}{W_m C} + \frac{(C-1)}{W_m C}\frac{P}{P_o}$$

Where, W is the weight of nitrogen adsorbed at a given P/P_o, and W_m the weight of gas to give monolayer coverage and C, a constant that is related to the heat of adsorption.

II. EXPERIMENTAL

The zeolite based catalysts used as adsorbents in this investigation such as zeolite, H-zeolite, Pt/Zeolite, Pd/Zeolite, Pt-Pd/Zeolite, Pt-Ce/Zeolite. The zeolite used was activated Indonesian natural zeolite. A portion was then exchanged with ammonium nitrate and it was heated up to produce H-zeolite. The metal was added to the support by impregnation method. The zeolite was dipped or immersed in a solution which contains noble metals. The noble metals will adhere to the surface of the support. After the impregnation, solvent was then evaporated at boiling temperature, the catalyst was dried in the oven overnight and thereafter the catalyst was activated under hydrogen stream of 10 mL/min for 2 hours. In the solution used for the impregnation, platinum has a valence of 4. The Pt^{IV} compounds that used for impregnation was hexachloroplatinic(IV) acid ($H_2 Pt^{IV} Cl_6$).

Prior to surface area and BET-*C* determination, the catalyst samples were evacuated by degassing at 250°C for 4 hours. All data were collected on the same instrument and were obtained at nitrogen P/P_o values of 0.08, 0.11, 0.14, 0.17 and 0.20.
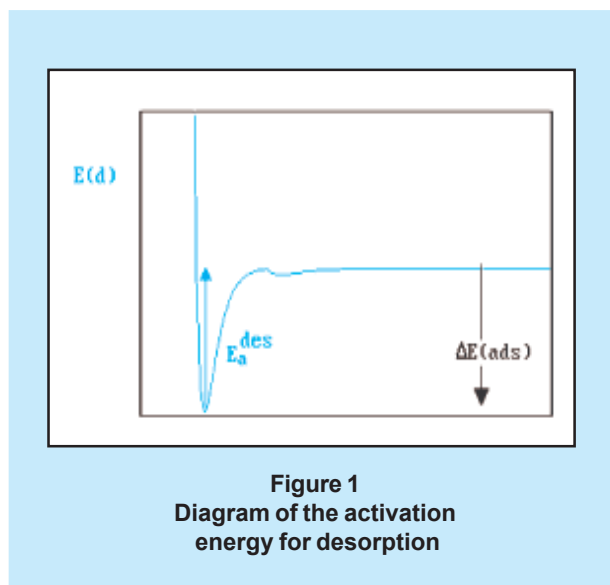

Figure 1
Diagram of the activation
energy for desorption

III. RESULT AND DISCUSSION

Surface area and BET-C data:

The adsorbents used for this experiment were zeolite, H-zeolite, Pt/Zeolite, Pd/Zeolite, Pt-Pd/Zeolite, Pt-Ce/Zeolite. The N_2 was used as adsorbate. The results of determinations of the BET-C and surface area of zeolite-based adsorbents are summarized in Table 2.

As seen in Table 2 that the surface area and the BET-C are depending on the present of metal in the zeolite based adsorbents. Bimetal adsorbent demonstrates a significantly higher BET-C than the zeolite itself as well as monometal/zeolite adsorbent. The results indicate that surface area and BET-C data increase with the increase of the metal content on the zeolite based adsorbent. This phenomenon proves that the adsorption of nitrogen by adsorbent is mainly caused by the metal-nitrogen interaction.

$$\Delta G^o_{adsorption} = -RT \ln K$$

Calculation of heat adsorption:

Considering adsorption process, the surface covered in monolayer, bilayers, and so on. The first layer of the adsorption,

$$K = e^{-\left(\Delta G^o_{adsorption}/RT\right)}$$

$$K = e^{\left(\Delta G^o_{desorption}/RT\right)}$$

A(g) + S $\rightleftharpoons$ AS

A = adsorbate   S = active sites   AS = Adsorbate adsorbed on the active sites

The relation between adsorption standard free energy changes and the adsorption equilibrium constant of this process is:

The second and further layer of the adsorption, the process is similar to condensation-evaporation.

A(g) $\rightleftharpoons$ A(liquid)

When, K_1 is the equilibrium constant for vapor condensation, the relation between condensation standard free energy changes and the condensation-evaporation equilibrium constant is:

$$\Delta G^o_{condensation} = -RT \ln K_1$$

$$K_1 = e^{-\left(\Delta G^o_{condensation}/RT\right)}$$

$$K_1 = e^{\left(\Delta G^o_{vaporization}/RT\right)}$$

Introducing a new constant used as a BET constant, C, the ratio between equilibrium constant of first layer adsorption to the second layer,

Table 1
Lists of some adsorbate cross-sectional areas

No.	Adsorbate	Area (Å)	ΔH_{vap} (kJ/mole)
1.	Nitrogen	16.2	2.79
2.	Ammonia	14.6	23.35
3.	Benzene	40.0	42.90
4.	Carbon dioxide	19.5	25.13
5.	Carbon monoxide	16.3	6.02
6.	Ethane	20.5	7.82
7.	n-Butane	46.9	21.00
8.	n-Hexane	51.0	28.96
9.	Oxygen	14.1	3.41
10	Water	10.8	40.65

Table 2
Surface area and BET-C
data of zeolite-based adsorbents

No.	Catalyst/ adsorbent	BET-C	Surface Area (m^2/g)
1.	Zeolite	85.82	47.31
2.	H-zeolite	92.05	98.66
3.	Pt/Zeolite	1426.27	129.14
4.	Pd/Zeolite	1114.53	108.56
5.	Pt-Pd/Zeolite	4376.03	109.38
6.	Pt-Ce/Zeolite	3527.99	111.28

$$C = \frac{K}{K_1}$$

$$C = \frac{e^{\left(\Delta G^o_{desorption}/RT\right)}}{e^{\left(\Delta G^o_{vaporization}/RT\right)}}$$

$$C = e^{\left(\Delta G^o_{desorption} - \Delta G^o_{vaporization}\right)/RT}$$

$$\Delta G^o_{adsorption} = \Delta H^o_{adsorption} - T\Delta S^o_{adsorption}$$

$$\Delta G^o_{condensation} = \Delta H^o_{condensation} - T\Delta S^o_{condensation}$$

The entropies of desorption and vaporization are similar,

$$\Delta S^o_{condensation} = \Delta S^o_{adsorption}$$

and

$$\Delta H^o_{condensation} = \Delta H^o_{adsorption} \quad or \quad \Delta H^o_{vaporization} = \Delta H^o_{desorption}$$

$$C = e^{-\left(\Delta H^o_{adsorption} + \Delta H^o_{vaporization}\right)/RT}$$

$$RT\ln C = \Delta H^o_{vaporization} - \Delta H^o_{adsorption}$$

$$\Delta H^o_{adsorption} = \Delta H^o_{vaporization} - RT\ln C$$

By knowing BET-C and the standard enthalpy of vaporization (ΔH^o_{ads} of N_2) at boiling temperature, the enthalpy of adsorption can be calculated. The results are listed in Table 3.

Using the basic principles of the adsorption theory fitted with the functions based on the BET adsorption model, the important data of BET-C can be shown. The value for the ΔH_{ads} (N_2) for

Table 3
Heat of adsorption of nitrogen on adsorbents

zeolite, H-zeolite, Pt/zeolite, Pt-Pd/zeolite, and Pt-Ce/zeolite calculated from the equation derived from BET-C are -3.67, -3.73, -5.99, -5.79, -6.92 and -6.75 kJ/mol respectively. There is a slightly difference values of the ΔH_{ads} (N_2) among the catalysts because of its calculation in thermal analysis. The value for the ΔH_{ads} (N_2) for Pt/zeolite is -5.61 ± 0.14 kJ/mol and the ΔH_{ads} (N_2) for Pd/zeolite is -5.58 ± 0.26 kJ/mol.

The data in Table 3 were calculated under the following assumptions: (1) Adsorbed molecules were always stay on top of the site, (2) Energy of adsorption was same for any layer other than the first layer, (3) A new layer could be started before another layer was finished. With these assumptions, there is a slight difference in the adsorption and desorption runs. It is due to the differences of observation in the adsorption and desorption isotherms. For alumina there is not much evidence of this case, but the path is more pronounced in the silica isotherm.

An alternative method to approach this adsorption problem is to use the Langmuir theory. The Langmuir theory differs from the BET theory slightly. The assumptions that is made in the Langmuir theory as follows: (a) Adsorption cannot proceed beyond monolayer coverage; (b) All sites are equivalent and the surface is uniform; and (c) The ability of a molecule to adsorb at a given site is independent of the occupation of neighboring sites. The Langmuir theory holds under low pressures whereas the BET theory may fail. The problem with the Langmuir theory is that at high pressures, there may be more than just monolayer coverage. In this investigation, heat of adsorption calculation is only based on the BET theory.

IV. CONCLUSION

The results obtained in this investigation showing that surface area measurements based on nitrogen adsorption is unique and useful for heat of adsorption calculation. This investigation shows that

the reason of why the BET-*C* is put to practical use in every time for surface area measurements.

Gas adsorption has been studied theoretically as the simplest of the resulting theories to provide the insight needed for most applications. It has been investigated such treatments that attributed to Brunauer, Emmett and Teller (BET) and apply their equations to our experimental data. The adsorption of N_2 at cryogenic temperatures is conducted on common high area catalysts. This information was then used to examine the simple adsorption theory and estimate the heat of adsorption of N_2.

The BET constant can be used to determine the heat of adsorption between the nitrogen as an adsorbate and zeolite based catalysts. The value for the ΔH_{ads} (N_2) for zeolite, H-zeolite, Pt/zeolite, Pt-Pd/zeolite, and Pt-Ce/zeolite calculated from the equation derived from BET-*C* are -3.67, -3.73, -5.99, -5.79, -6.92 and -6.75 kJ/mol respectively.

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