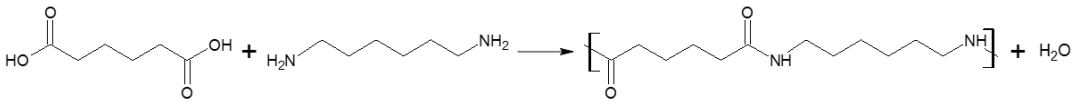
CHAPTER 1 SOLUTIONS

1.1 (a) Wallace Carothers

(b) The main reaction for making nylon is:



Adipic Acid Hexamethylene diamine Nylon-6,6

(c) Water is removed by molecular sieve.
(d) Hexamethylene diamine
(e) A glass assembly was constructed to observe the spinning process, in order to identify the reasons for broken threads and clogged orifices in the spinneret. It was found that the gas bubbles given off during the polymer decomposition broke the fiber upon passing through the spinneret hole. The problem was solved by keeping the polymer under pressure, which dissolved the bubbles harmlessly into the molten mass.
(f) Seaford, Delaware

1.2 Polyvinyl butyral can be synthesized by the following reactions:

Step 1:

Vinyl acetate is synthesized by reacting ethylene and acetic acid with oxygen in the presence of catalysts:

$$CH_2 = CH_2 + CH_3COOH + \frac{1}{2} O_2 \rightarrow CH_3COOCHCH_2 + H_2O$$

Step 2:

Polyvinyl acetate (PVAc) is synthesized by the free radical polymerization of vinyl acetate:

$$n\ C_2H_3OOCCH_3 \rightarrow [CH_2CH(OAc)]_n$$

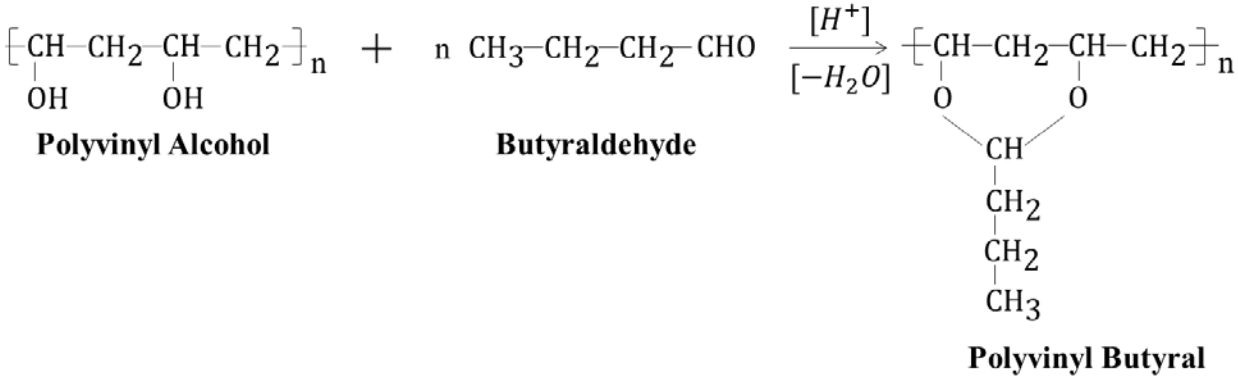
Step 3:

PVA is synthesized by the alcoholysis of PVAc:

$$[CH_2CH(OAc)]_n + n\ CH_3CH_2OH \rightarrow [CH_2CH(OH)]_n + n\ C_2H_5OAc$$

Step 4:

Polyvinyl butyral is synthesized by reacting PVA and butyraldehyde under acidic conditions:



Polyvinyl Alcohol + **Butyraldehyde** → **Polyvinyl Butyral**

1.3 (a) BASF ($79,760 million), Dow Chemical ($56,786 million), Sinopec ($56,442 million), Shell ($42,715 million), SABIC ($42,201 million)

(b) Sinopec, Reliance Industries, LG Chem, Lotte Chemical, SK Innovation; none from Thailand

(c) Sinopec

(d) BASF ($ 2,204 million), DuPont (2,067 million), Dow Chemical (1,708 million), Bayer (1,317 million), Evonik Industries (505 million)

(e) Eastman Chemical purchased Solutia.

1.4

Business sector	**Examples**
Oil companies	Shell, ExxonMobil, Chevron, BPAmoco, Texaco, Royal Dutch Shell, Sinopec, China National Petroleum, Saudi Aramco, Conoco Phillips, Total, Gazprom, Eni, Petrobras, Pemex, Statoil, Lukoil, National Iranian Oil, Petronas, Indian Oil, Repsol, China National Offshore Oil, Marathon Petroleum, Pertamina, Rosneft, Idemitsu Kosan, OMV Group, Sunoco, Bharat Petroleum, GS Caltex, and so on.
Chemical companies	DowDuPont, BASF, Bayer, Sinopec, SABIC, Royal Dutch Shell, Formosa Plastics, LyondellBasell, Ineos, Mitsubishi Chemical, LG Chem, AkzoNobel, Braskem, Mitsui Chemicals, Sumitomo Chemical, Reliance Industries, Evonik Industries, Toray Industries, Lotte Chemical, Yara International, PPG Industries, Solvay, DSM, Shin-Etsu Chemical, SK innovation, Asahi Kasei, Huntsman, and so on.
Gas companies	Air Liquide, The Linde Group, Towngas, Praxair, and so on.
Specialized engineering firms	KBR, Arthur D. Little, Schlumberger, UOP, and so on.
Pharmaceutical companies	Merck, Johnson & Johnson, Bristol-Myers Squibb, Pfizer, Regeneron Pharmaceuticals, Roche, Schering Plough, Novartis, Sanofi, Glaxo SmithKline, AstraZeneca, Lilly, AbbVie, Teva Pharmaceutical Industries, Amgen, Takeda, Boehringer Ingelheim, Novo Nordisk, Bayer, Astellas, Pharma, Daiichi Sankyo, Otsuka, Gilead Sciences, Baxter, and so on.
Food companies	Unilever, General Mills, Nestle, Archer Daniels Midland, Cargill, Hershey, PepsiCo, Associated British Foods PLC, Coca-Cola, Groupe Danone S.A., Kellogg Co., Mars, Mondelez International, Tyson Foods, Anheuser-Busch InBev, Smithfield Foods, ConAgra Foods, Dean Foods, Hormel Foods, Saputo, and so on.
Consumer goods companies	Procter and Gamble, Unilever, 3M, , Mead Corporation, L'Oreal, Shiseido, Avon Products, Colgate-Palmolive, Reckitt Benckiser, and so on.

1.5 From DuPont's website (www.dupont.com):

Market Sector	Molecules	Formulated Products	Functional Products	Device/ Equipment
Agriculture	Nicosulfuron (used in Accent® Herbicide)	Fertilizer mixture	Pioneer®Sunflower seed	NA
Automotive	Polyvinyl butyral	Lubricants and greases	PBT thermoplastic polyester resin (polybutylene terephthalate)	NA
Building & Construction	ISCEON®M029 (a refrigerant)	Acrylic caulk & silicone sealant	Corian (Acrylic polymer + alumina trihydrate)	NA
Electronics	OLED materials	Silver conductive ink	Polyimide film	NA
Energy	Enzyme	Silicon ink	Nomex fabric (an Aramid)	Solar panel
Food & Beverage	D-Xylose	GRINDSTED®PECTIN	HOWARU@Prem-imum Probiotics	BAX® System X5
Health Care & Medical	1,1,1,2 tetrafluorethane (used in Dymel®Propel-lants for pharmaceutical use)	SoBind™ Harmony (water-soluble soy polymers)	Tynex®Nylon toothbrush filaments	NA
Packaging & Printing	Ethylene copolymer (used in Appeel)	Artistri®Inks for digital textile printing	Appeel®lidding sealant resins	NA

1.6 (a) Ultrathon insect repellent:
Formulation developed for and used by the US Military with patented controlled release technology; Up to 12 hours of protection against mosquitoes; Repels deer ticks that may carry Lyme disease and mosquitoes that may carry West Nile Virus.

(b) Filtrete air purifier:
Claimed to be the quietest air purifier available; Filter captures 99.9% of large airborne allergens like pollen, mold spores, and dust mite debris; Filter also captures household dust, pet dander, bacteria, and particles that can carry viruses, smoke, and smog; for room sizes: 350 sq. ft.; with filter change timer included; offer easier filter change; and with a 3 speed fan.

(c) Water pitcher and replacement filter:
Filters and fills 5X faster (than traditional filtering pitchers); Holds more water in less space; Filter lasts longer, filtering two and a half times more water than traditional pitcher filters (up to 100 gallons or for approximately three months); Reduces sediment, chlorine taste and odor; The replacement filter filters up to 100 gallons, approximately 3 months.

(d) Sun control window film
High visible light transmission providing excellent aesthetics; Up to 97% infrared rejection providing energy savings and enhanced comfort; Low interior and exterior reflectivity enhances views while maintaining exterior appearance; Non-metallized film with no interference with wireless communications and no chance for corrosion; Helps extend the life of furnishings by significantly reducing harmful UV rays, the largest cause of fading; Comprehensive warranty from 3M up to 15 years.

(e) Reusable cold/hot pack
Flexible ice or soothing heat; Cold for pain and swelling, heat for muscle aches and stiffness; Includes a protective cover with elastic strap to secure pack in place.

1.7 (a) Soap
Unilever: Dove
P&G: Safeguard

(b) Skin cream
Unilever: Dove, Vaseline, Pond's
P&G: Olay

(c) Shampoo
Unilever: Dove, Sunsilk, LUX, AXE, Simple, TRESEMMÉ
P&G: Head & Shoulders; Pantene; SK-II

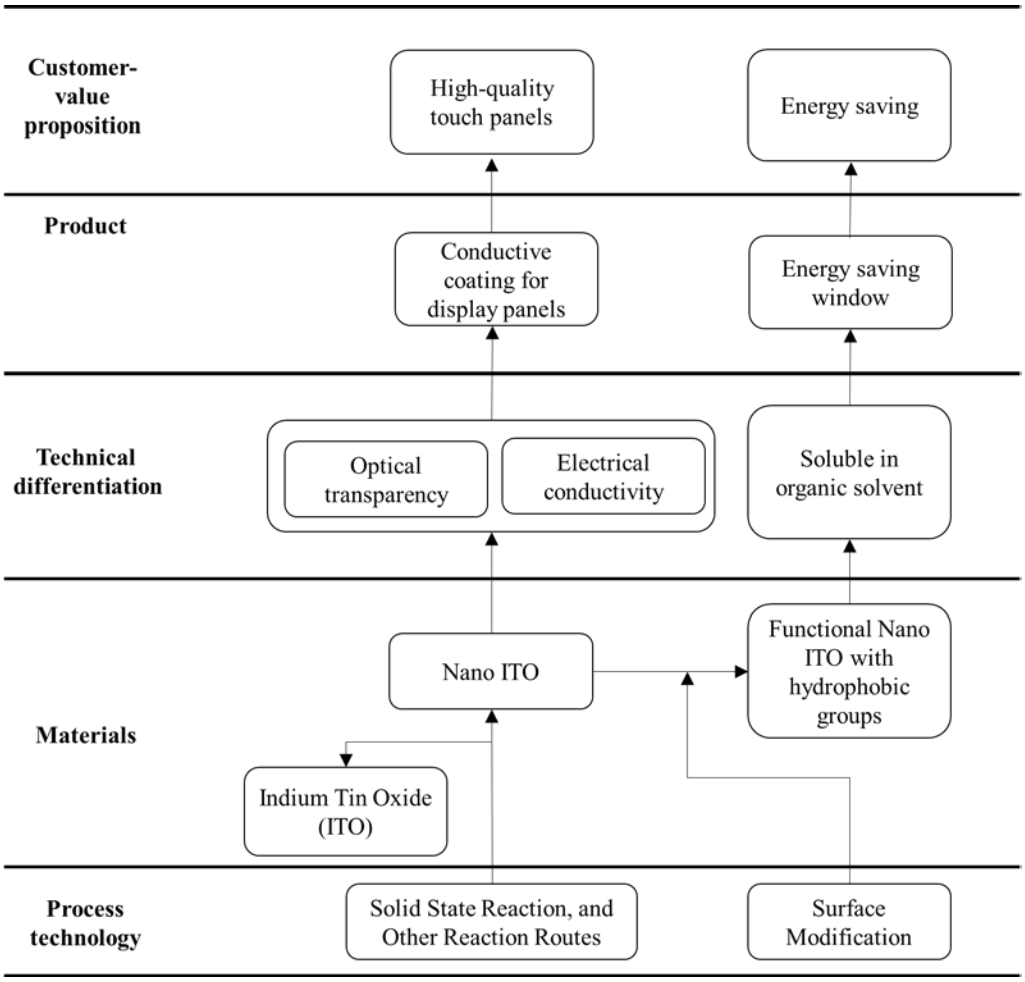
(d) Laundry detergent
Unilever: Comfort, Sunlight, Surf
P&G: Ariel, Gain, Tide

1.8 In the two identified sunscreen lotion products:

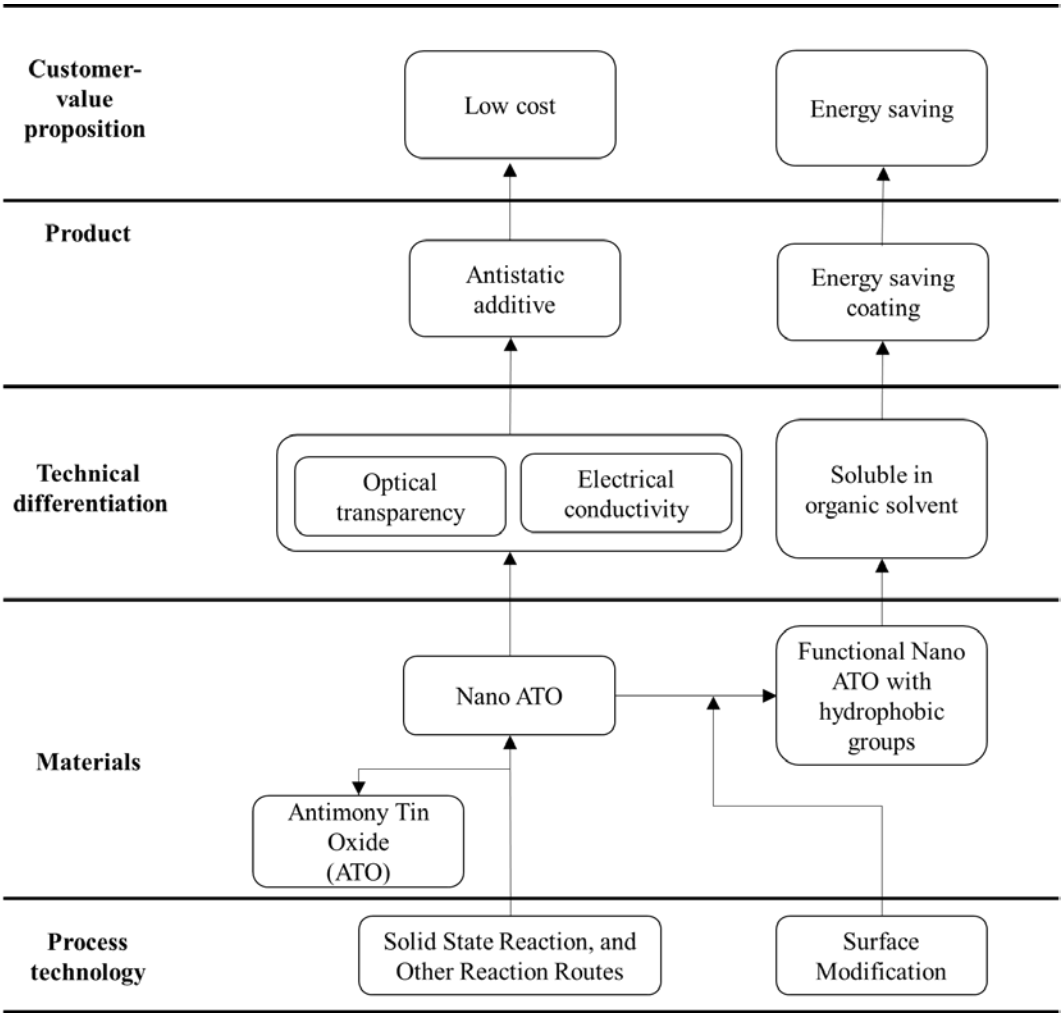
NIVEA SUN Moisturising Sunscreen Lotion provides UVA and UVB protection with octocrylene, titanium dioxide, and other ingredients. Two different SPFs, 30+ and 50+, are available. It also prevents skin dehydration with the moisturizers. Vitamin E is included in the lotion.

Neutrogena® Ultra Sheer® Dry-Touch Sunscreen SPF 30 provides both UVA and UVB protection and is water resistant for 80 min. It is offered with SPF 30 only and the product is based on a technology called Helioplex®.
Most of the information on the product is related to functional product attributes, including the SPF and water resistant capability. Regarding physical and sensorial product attributes, it is claimed that the product is not oily**.** There is no information on its rheological attributes.

1.9 The innovation map for indium tin oxide:



The innovation map for antimony tin oxide:



1.10 Using the keyword “skin care”, we got

(a) Avon Products, Inc., 622
(b) Kanebo Limited, 10
(c) L'oreal, 7340
(d) Revlon Consumer Products Corporation, 120
(e) Shiseido Company, Ltd., 334

The website was accessed on Jun 16, 2016. Because some of the patents are simply the same patent filed in different countries. The number shown here may be slightly larger than the number of distinct patents the company owns.

1.11 (a) Fishbone diagram

Fishbone diagram is a visual tool to identify, explore and graphically display, in increasing detail, all of the suspected possible causes related to a problem or condition to discover its root causes. It focuses the team on causes not symptoms. The goal is to discover the most probable causes for further analysis. The possible relationships between the causes for any current or future problems are clarified.

(b) Pareto analysis

Pareto analysis is a formal technique useful when many possible courses of action are competing for attention. This technique helps to identify the top 20% of causes that needs to be addressed to resolve the 80% of the problems. A Pareto chart is a graphical representation that displays data in order of priority.

(c) Process analytical technologies (PAT)

PAT is a system for designing, analyzing, and controlling manufacturing through timely measurements (i.e., during processing) of critical quality and performance attributes of raw and in-process materials and processes with the goal of ensuring final product quality. Product testing alone is not sufficient to ensure that a process consistently produces a product with predetermined specifications. Adequate process design, knowledge and control of factors that produce process variability, and successful process validation studies, in conjunction with product testing, provide assurance that the process will produce a product with the required qualities.

(d) Quality by design (QbD)

QbD is a concept that quality could be planned, and that most quality crises and problems relate to the way in which quality was planned in the first place. Unambiguous design inputs including analysis of field experiences/ performances. Design reviews at each product development stages by early involvement of all stakeholders and strong change management processes are necessary.

(e) Root cause analysis

Root cause analysis is a process for identifying causal factors that underlie variations in performance associated with adverse events or close calls. It features interdisciplinary involvement of those closest to and/or most knowledgeable about the situation. We begin with a flow diagram of “what happened?” which trigger questions to expand this view. This is followed interviews with those involved or those with a similar job and by site visits and simulation to augment the analysis.

(f) Taguchi method

Taguchi method is a structured approach for determining the “best” combination of inputs to produce a product or service. It uses Design of Experiments (DOE) methodology for determining the parameter values. DOE which quantitatively identifies the right inputs and parameter values for making a high quality product or service is an important tool for designing processes and products.

1.12 (a) The double low-E double-pane insulating glass units (IGUs) is composed of two panes of glass separated by an aluminum spacer with air or argon in the space between the panes. Desiccants to remove the moisture trapped in the gas space to prevent condensation. Low e-coating applied on the inside of the outer glass pane reflects thermal radiation without compromising much on visible light transmission.

Materials	**Supplier**
Glass	Saint-Gobain
Low-e coating	Saint-Gobain
Aluminum spacers	Hi-Tech Glazing Supplies
Sealants	BASF
Silica gel desiccants	Desican Inc.
Argon gas	Praxair Technology Inc.

(b) Step 1. Preparation of the low-E coating coated glass panes:

Low-E coatings can be divided into two major groups, passive low-E coatings and solar control low-E coatings, which are manufactured by different processes.
Passive low-E coatings coated glasses are fabricated by pyrolytic process, where the coating is applied on the hot glass surface when it is being produced on the float line. Solar control low-E glasses are fabricated by sputtering, where the coating is applied to pre-cut glass in a vacuum chamber at room temperature.

Step 2. Assembly of the insulated glass units:

The dimensions and specifications, including glass type and thickness, of the IGUs, are determined. After assembling the different parts of and sealing the IGU, two holes are drilled into the spacer to replace the air in the space with argon. After sealing the holes, the edges are sealed with another sealant, usually polysulfide or silicone sealant, to prevent the moisture in the outside air from entering the gas space of the IGU.

(c) Beijing Northglass Technologies Co., Ltd.; Rizhao Jinbo Industry Co., Ltd. ; and Qingdao Globalstar Glass Technology Co., Ltd.

1.13 (a) A rechargeable cylindrical lithium-ion battery is composed of a cathode film (lithium-iron phosphate) and an anode film (graphite) separated by a separator (polyethylene). They are rolled up and inserted into a cylindrical metal shell.

(b)

Materials	**Supplier**
Lithium-iron phosphate	Linyi Gelon LIB Co., Ltd.
Graphite	Qingdao Haiyongchang Graphite Co., Ltd.
Polyethylene separator	Celgard

(c) Anode materials are mixed in a mixer and then coated on a copper film. This is repeated for cathode materials which are coated on an aluminum film. The solvent in the electrode coat is removed by drying. The film porosity is minimized by the means of compression. The electrode films are cut to the required size, rolled up, and inserted into a metal shell. Afterwards, the cell is evacuated, filled with electrolyte, and then sealed and cleaned in a dry room. The manufactured cells are then charged and discharged gradually increasing voltage for 2 to 4 weeks. After performance evaluation, the cells are now ready for sale.