Appendix I

Future Challenges for Chemical Engineers and Chemical Engineering

This kind of list or discussion will be highly dependent on both the author and their experiences and viewpoints. Having said that, here are some future challenges that chemical will impact with the skills and knowledge of chemical engineers:

1) Energy Resources and Use. In this context, we need to put aside "agendas" that may have political constituent drivers as their prime concern (e.g., corn-based ethanol). Energy is required to feed people, house people, and allow them to move from place to place. Unless we decide to move back to a total agrarian culture and reduce our standard of living, more efficient sources of energy will be required as global population continues to grow and what we refer to now as "Third World" countries demand conventional standards of living long known in the Western world. As a recent example, a breakthrough has occurred fundamentally in understanding of underground fluid flow and mechanics, which we commonly refer to as "fracking," allowing the recovery of hydrocarbons, previously locked in underground rock formations, via the injection of high-pressure fluids to break them apart. Enhanced oil recovery adds additional surface chemistry technology to the basic practice of drilling holes in the ground into reservoirs of liquid.

   Energy conservation will be equally important. It is unrealistic to think that Third World populations will not desire the same kind of conveniences that most people in advanced societies enjoy, and if this is to happen, increased energy supplies as well as more efficient energy utilization will be required. We have already seen, in the last few decades, dramatic increases in energy efficiencies across many industries and products, driven in part by the rise in the price of energy. Though this has taken a turn the other way in recent years, once these energy conservation changes are put in place, it is unlikely that they will be reversed. As part of this effort, progress in solar energy conversion will advance steadily. Though solar energy is available globally at a far higher amount than we need, its energy density is miniscule

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compared to hydrocarbon fuels. There has been steady progress to improve the efficiency of solar power conversion to both thermal and electrical energy, but it is still far from sufficient to support a solar economy. Chemical engineers will play a key role as this technology advances in terms of catalysts, collection material efficiencies, and energy distribution technology.

2) Water. With a growing global population and the small percentage of water resources being immediately usable for drinking water, using non-fresh water drinking supplies as well as recycling and reusing water is a grand challenge. Potable water, in combination with food and energy, is what is sometimes called the "great nexus" of engineering challenges for the 21st century.
3) Materials. There are two long-term aspects to this topic in which chemical engineering will be heavily involved. The first, and most commonly discussed, is plastics recycling. As we discussed in Chapter 17 regarding how polymeric materials are typically made, they are long chains of monomers, typically requiring significant energy input in both their monomer production and the polymer itself. The separation of plastics into easily reusable materials is very costly and inefficient and rarely produces materials that are as usable as the original starting materials. The cost of the separation process itself (polyethylene, polystyrene, ABS, nylon, etc.) is rarely justified economically but is instead subsidized through taxpayer funding. The properties of the polymer, during such a process, typically degrade in some way, primarily through reduction in molecular weight, making them unusable for their original market. We see many examples of products in the store with a label saying "contains up to 10% recycled materials." If more were added, the properties the user is paying for would not be achievable. Several things will happen long term, all requiring significant chemical engineering input. The first is separation technologies that may allow more economical separation of different types of discarded plastics, allowing a higher level of use in original products. The second is a reduction in the amount of plastics used through redesign of packaging and other systems. For example, there may be cases where a large plastic package may be reduced to a "shrink wrap" type of package utilizing far less plastic. It may also be possible to eliminate traditional packaging altogether with various types of coatings. Thirdly, economical pyrolysis processes (heating of materials to high temperature in the *absence* of air, the opposite of combustion) may allow the plastics to be converted back into their starting monomers (i.e., polystyrene to styrene, polyethylene to ethylene, polypropylene to propylene, etc.) producing traditional hydrocarbon monomers that are much easier to separate via traditional chemical engineering unit operations such as distillation and also allow their use in any application, not just for the plastic from which they originated. Work is going on in all of these areas, but the latter is probably the most robust option long term.

Under this heading we must also list "nanomaterials" that are now finding their way into consumer products to provide unique functionality. There is still ongoing debate and data analysis of the potential impact of 10^{-9} particle size materials and their distribution within the environment. However, these size materials have dramatic positive impact on many material properties. The surface chemistry, interface with other materials, and the economical production of such materials will be major challenges for both chemists and chemical engineers. Any separation process will perform significantly different when the particles to be separated are in this size range.

In the periodic table we reviewed earlier, there is a class of compounds known as "rare earth" metals. Examples include metals such as dysprosium and neodymium. Many of these types of materials, in small quantities, are used to improve the properties of base metals. They are rare in their occurrence and expensive to manufacture. There is a major chemical engineering challenge in reducing the cost of their recovery and production, as well as finding alternative materials and product designs that do not require these kinds of rare materials.

4) Medical, Biomedical, and Biochemical Applications. We have all heard of and seen examples of artificial organs now used routinely. If we really consider what artificial hearts and kidney dialysis machines do, they are simply pumps and filters—chemical engineering replacements for original human body parts. All of the concepts we have discussed, including fluid flow, fluid properties, polymers, and filtration, are the basis for the design of these artificial organs. As we progress in understanding of human body functionality, it is likely that we will see additional artificial and replacement organs and body parts where chemical engineering fundamentals are instrumental in their design. Examples could include artificial lungs, replacement joints, and body fluid processing. A core part of any of these types of products are chemical engineering principles related to fluid flow, friction, filtration fundamentals, porosity, pressure drop, and many others. In many schools today, the chemical engineering department has been combined with this type of research and is renamed as biochemical engineering or biomedical engineering.

An artificial heart is a synthetic replication of the normal human heart, but from a chemical engineering viewpoint, it is simply a pump. All the aspects of pump design (friction, energy requirements, flow rates, valve restriction and control, etc.) apply equally to such devices as they do to conventional pumps except that the restrictions on energy available and friction and pressure drop are much more limited. The materials from which we make these devices must also be compatible with human tissue so that they are not rejected. This is a far more sophisticated issue than corrosion concerns discussed earlier as incompatibility is not an issue simply of material degradation but of possible loss of human life.

There are many prescription drugs that are much more desirable to be taken on a small dosage basis continuously rather than large dosages once or twice a day. The encapsulation and slow release of these types of drugs via a skin patch is becoming more common. The encapsulation and slow release of a drug is a result of understanding the mass transfer rates through the skin and how to match this absorption rate with an encapsulation technique that releases the drug at the same rate.

This is in no way a complete list of future chemical engineering challenges and where chemical engineering skills will be useful, and all readers are encouraged to think about their own business and technical world and where chemical engineering principles could be used in a positive way.

Biochemical engineering is the combination of chemical engineering and biology in a way to scale up and produce useful medical products and systems. From a chemical engineering standpoint, there are a number of unique challenges in this task. If we refer back to our review of membrane materials, we see that biological molecules such as viruses and proteins have particle sizes in the range of 0.01–10 μm, far smaller than the usual particle sizes produced in conventional inorganic and organic chemical reactions. This makes separation and recovery of active, desired molecules far more difficult and requires the use of the far more expensive and sophisticated recovery processes.

Most biochemical entities which are processed start with very dilute solutions. The combination of this factor and the particle size makes liquid–solid separation a major challenge in this area, especially as it relates to pharmaceutical and FDA purity requirements.

Most biological materials exist and perform their function at body and ambient conditions. Thus, it is not possible to run most reactions at higher temperatures where reaction rates might be accelerated. This fact may also put limits on other unit operation concepts for consideration.

The potency of many biopharmaceuticals and drugs is such that the amount of material actually needed for a significant market may be the equivalent of a small pilot plant in the traditional chemical or petrochemical area. Some of the scale-up guidance discussed earlier would not necessarily apply; however, the need and drive for efficient production and high yields of extremely valuable materials is no less important. Challenges in formulating the drug into a suitable form for human consumption, including such variables as its dissolution rate in the stomach and gastric tract, and the inert ingredients required, are substantial.

Stereo specificity is not a concept normally considered in conventional chemical engineering and processing. However, it is very important in the design and manufacture of biologically active molecules and was discussed previously in Chapter 17. The carbon atom, with its normal four bond linkages, is unique in that is, geometrically, a pyramid with the "C" molecule at the center. When the four molecules attached to this carbon are different, there is the possibility that the carbon will be "chiral," meaning that it will not be symmetrical in terms of geometry. One of the side groups will appear (if drawn on a piece of paper) to be going into the paper while the other jutting out. This distinction is known as "left-hand" and "right-hand" rotated molecules (or D-, L-; meaning dextro or levo rotated, respectively). This is important in biologically related or active molecules (such as drugs) in that our human body only recognizes and interacts with L- (levo) rotated molecules. These two different chirally rotated molecules are known as *enantiomers*, meaning that they are not superimposable upon each other, no matter how the molecule is rotated physically.

Our bodies only recognize and process "levo" or "L-" rotated molecules, so everywhere an optical isomer exists, it means that there is an identical molecule produced in the same concentration which may have to be separated prior to the material's use. This "non-absorption" of the opposite isomer is the basis for some artificial sweeteners in the market whose structure is "right handed." We perceive the taste of the molecule (sweetness), but our bodies do not absorb it and it becomes part of normal body fluid waste. The difference between left- and right-handed oriented molecules is described as different "enantiomers."

It is not always necessary to separate the enantiomers (depending on possible negative impact of the other optical isomer), but when it is, there are some important impacts on chemical engineering process decisions. The primary one is that these molecules, though they have different "optical" properties, have the same physical properties such as boiling or melting points. This makes it impossible to separate these enantiomers by such conventional, and lower cost, unit operations such as distillation. There can be small differences in solubility characteristics which can be used in crystallization schemes as well as chromatography and special ion-exchange resins.

In addition to the primary challenges mentioned earlier, we also have the challenge of slow reaction rates. Most biological processes have very slow kinetic rates compared to conventional chemical reactions, and due to the limitations of temperature sensitivity, the ability to raise temperatures during such processes as tissue culture growing is very limited. Agitation is usually required in biochemical reactions as it is in other chemical reactions; however the physical sensitivity to mechanical forces may require special designs.

It is also important to note that chemical engineers, with their strong background in safety, can also contribute to safety analyses of biochemical processes and products. The potential release of harmful, biochemically active materials with small particle sizes, such as viruses, is always of concern, and chemical engineering expertise in gas handling and filtration can be used.

Additional Resources

Benz, G. (2016) “Optimizing Aerobic Fermenter Operation” *Chemical Engineering Progress*, 3, pp. 60–62.

Harrison, R. (2014) “Bioseparation Basics” *Chemical Engineering Progress*, 10, pp. 36–42.

Levesque-Tremblay, G. (2016) “Bio-Molecular Engineering: Little Bio-Machinery to Solve Grand Challenges” *Chemical Engineering Progress*, 4, p. 23.

Ruan, G. and Winter, J. (2012) “Chemical Engineering at the Intersection of Nanotechnology and Biology” *Chemical Engineering Progress*, 12, pp. 38–40.

Tryzbycien, T. and Hooker, N. (2015) “Continuous Processing in Downstream Operations” *Chemical Engineering Progress*, 12, pp. 38–44.

Wibowo, C. and O’Young, L. (2005) “A Hybrid Route to Chirally Pure Products” *Chemical Engineering Progress*, 11, pp. 22–27.

Wispelwey, J. “Drug Delivery and Chemical/Biological Engineering” (2013) *Chemical Engineering Progress*, 3, p. 18.

Appendix II

Additional Downloadable Resources

Note: This list is in no way a comprehensive list, nor does it imply any endorsement on the part of the author or publisher. It does not include purchasable material and books that are available for any of these topics. This list supplements the articles listed at the end of each chapter from AIChE's flagship publication, *Chemical Engineering Progress*. Any industrial web sites listed here are only because of useful general information and illustrations and again do not imply any endorsement by the author or the publisher.

General

http://www.aiche.org
http://www.engineeringtoolbox.com
http://accessengineeringlibrary.com/browse/perrys-chemical-engineers-handbook-eighth-edition

1. Chapters 1–3

MSDS sheet requirements: https://www.osha.gov/Publications/OSHA3514.html
MSDS sheet example: propane http://airgas.com/msds/001045.pdf

2. Flammability Limits and Explosion Pressure Information for Compounds

https://en.wikipedia.org/wiki/Flammability_limit
http://www.engineeringtoolbox.com/explosive-concentration-limits-d_423.html
http://www.chemicalbulletin.ro/admin/articole/25469art_13%2858-61%29.pdf
http://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/fompa.pdf

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3. Accelerating Rate Calorimetry

https://www.youtube.com/watch?v=CoIL_wWx3GQ

4. Periodic Table

http://www.chemicalelements.com/

5. Reaction Kinetics and Equilibrium

https://en.wikipedia.org/wiki/Chemical_kinetics
https://www.khanacademy.org/science/chemistry/chem-kinetics/reaction-rates/v/rate-of-reaction
http://www.csus.edu/indiv/m/mackj/chem142/kinetics.pdf
https://www.chem.tamu.edu/class/majors/tutorialnotefiles/factors.htm

6. Flow Sheets and Economics

https://en.wikipedia.org/wiki/Process_flow_diagram
https://chemengineering.wikispaces.com/Process+flow+diagrams
http://coade.typepad.com/coadeinsider/2009/06/CEP-May-09-Piping-and-Instrument-Diagrams-COADE.pdf
http://ocw.mit.edu/courses/chemical-engineering/10-490-integrated-chemical-engineering-i-fall-2006/projects/eng_econ_lecture.pdf

7. Fluid Flow and Pumps

https://www.khanacademy.org/science/physics/fluids/fluid-dynamics/v/fluids-part-7
https://en.wikipedia.org/wiki/Fluid_dynamics
https://en.wikipedia.org/wiki/Pump

8. Heat Transfer and Heat Exchangers

https://www.wisc-online.com/learn/natural-science/earth-science/sce304/heat-transfer-conduction-convection-radiation
http://www.physicsclassroom.com/class/thermalP/Lesson-1/Methods-of-Heat-Transfer

https://www.khanacademy.org/partner-content/mit-k12/mit-k12-physics/v/heat-transfer
https://www.youtube.com/watch?v=iIRbhZY8MpE
https://www.youtube.com/watch?v=Jv5p7o-7Pms
https://www.youtube.com/watch?v=seCA3Awv1Qk

9. Reactive Chemicals

https://www4.uwm.edu/usa/safety/chem/reactive.cfm
http://www.aiche.org/ccps/topics/process-safety-technical-areas/chemical-reactivity-hazards/reactive-material-hazards
http://www.ehs.utoronto.ca/resources/whmis/whmis5.htm
https://eta-safety.lbl.gov/sites/all/files/Water%20Chemicals%20-%20common%20list.pdf
http://www.usf.edu/administrative-services/environmental-health-safety/documents/labsafety-highlyreactive.pdf
https://www.youtube.com/watch?v=sRuz9bzBrtY (Bhopal)
http://people.clarkson.edu/~wwilcox/Design/reac-haz.pdf

10. Distillation

http://www.chem.umass.edu/~samal/269/distill.pdf
https://www.youtube.com/watch?v=gYnGgre83CI
https://www.youtube.com/watch?v=hC1PKRmiEvs
http://www.britannica.com/science/distillation
http://www2.emersonprocess.com/siteadmincenter/PM%20Rosemount%20Documents/3051S_ASP_Distillation_Column_Flooding.pdf

11. Other Separation Processes

https://www.cpp.edu/~tknguyen/che313/pdf/chap5-1.pdf
http://www.slideshare.net/abhijitcool18/gas-absorption-53768813
http://www.separationprocesses.com/Absorption/GA_Chp03.htm
https://www.youtube.com/watch?v=jtzoB3MOqxE
http://encyclopedia.che.engin.umich.edu/Pages/SeparationsChemical/Strippers/Strippers.html
http://www.academia.edu/5044422/Mass_Balances_on_CO_2_Absorption_Stripping_Process_Module_1_Material_Balances_on_Absorption_Stripping_Process_Module_Author
https://en.wikipedia.org/wiki/Adsorption

http://www.rpi.edu/dept/chem-eng/Biotech-Environ/Adsorb/adsorb.htm
http://www.lenntech.com/library/adsorption/adsorption.htm
http://www.chem.qmul.ac.uk/surfaces/scc/scat2_3.htm
https://en.wikipedia.org/wiki/Chromatography
http://www.explainthatstuff.com/chromatography.html
http://www.slideshare.net/bejoybj/advanced-chromatography-technique
http://www.novasep.com/technologies/chromatography-for-large-scale-bio-industrial-applications.html
http://www.kochmembrane.com/Learning-Center/Technologies.aspx
http://www.newterra.com/sites/default/files/pictures/newterra_membrane_brochure_sep2014.pdf

12. Evaporation and Crystallization

https://en.wikipedia.org/wiki/Evaporation
http://www.encyclopedia.com/topic/evaporation.aspx
http://www.entropie.com/en/services/evaporation/applications/
https://en.wikipedia.org/wiki/Crystallization
http://www.pharmoutsourcing.com/Featured-Articles/146653-Industrial-Crystallization-of-Pharmaceuticals-Capability-Requirements-to-Support-an-Outsourcing-Paradigm/

13. Filtration

https://en.wikipedia.org/wiki/Filtration
http://www.eaton.eu/Europe/Filtration/index.htm
http://www.quantrol.com/products.php?category=14&subcategory=214
https://www.youtube.com/watch?v=M4wBd1_CvNw
https://www.youtube.com/watch?v=iQAxVqCL2rk
https://en.wikipedia.org/wiki/Rotary_vacuum-drum_filter
http://www.komline.com/docs/rotary_drum_vacuum_filter.html

14. Drying

https://en.wikipedia.org/wiki/Fluidized_bed
https://en.wikipedia.org/wiki/Rotary_dryer
https://en.wikipedia.org/wiki/Rolling_bed_dryer
http://www.bepex.com/systems/thermal-processing/drying/
http://www.gea.com/global/en/binaries/GEA%20Barr-Rosin%20-%20Industrial%20Drying%20Brochure%20-%20English%20-%20US%20letter_tcm11-23426.pdf

15. Solids Handling

http://www.aiche.org/topics/chemical-engineering-practice/solids-handling-particle-technology
http://www.gre.ac.uk/engsci/research/groups/wolfsoncentre/home
http://www.slideshare.net/physics101/storage-bins-and-hoppers
http://www.aiche.org/academy/courses/els102/flow-solids-bins-hoppers-chutes-and-feeders
http://www.inti.gob.ar/cirsoc/pdf/silos/SolidsNotes10HopperDesign.pdf
https://www.aiche.org/sites/default/files/cep/20131125_1.pdf
http://www.chemengonline.com/hopper-design-principles/?printmode=1
http://www.academia.edu/5770816/SCREW_CONVEYOR_BASIC_DESIGN_CALCULATION_CEMA_Conveyor_Equipment_Manufacturer_Association_Approach
http://www.kwsmfg.com/services/screw-conveyor-engineering-guide/horsepower-calculation.htm
http://www.aiche.org/sites/default/files/docs/webinars/JacobK-PneumaticConveyingPDFmin.pdf
http://blog.bulk-online.com/general/65.html
http://jenike.com/engineering/pneumatic-conveyors/

16. Tanks and Vessels

http://jenike.com/engineering/pneumatic-conveyors/
https://en.wikipedia.org/wiki/Pressure_vessel
http://www.slideshare.net/ledzung/storage-tanks-basic-training-rev-2
http://www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=61B26EE8-1&offset=10&toc=show

17. Polymers and Plastics

https://en.wikipedia.org/wiki/Polymer
http://www.pslc.ws/macrog/kidsmac/basics.htm
https://www2.chemistry.msu.edu/faculty/reusch/virttxtjml/polymers.htm
http://matse1.matse.illinois.edu/polymers/ware.html
https://en.wikipedia.org/wiki/Plastic
https://www.plasticsindustry.org/aboutplastics/
http://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf
http://resource-recycling.com/pru_mag
https://en.wikipedia.org/wiki/Category:Plastics_additives

http://www.intertek.com/polymers/analysis/additives/
http://www.slideshare.net/devraj87india/additives-in-plastics

18. Process Control

https://en.wikipedia.org/wiki/Process_control
http://www.eng.unideb.hu/userdir/deak.krisztian/BOOK.pdf
http://www.itl.nist.gov/div898/handbook/pmc/section1/pmc13.htm
http://www.engineeringtoolbox.com/process-control-systems-t_32.html
http://nptel.ac.in/courses/103105064/
http://www.learncheme.com/screencasts/process-controls

Appendix III

Answers to Chapter Review Questions

Chapter 1 Review: What Is Chemical Engineering?

1 Chemical engineering is a blend of:
A __Lab work and textbook study of chemicals
B X Chemistry, math, and mechanical engineering
C __Chemical reaction mechanisms and equipment reliability
D __Computers and equipment to make industrial chemicals
Answer: (b) Chemistry, math, and mechanical engineering. Though chemical engineering includes the other answers, they are only minor parts of a larger description.

2 Major differences between chemistry and chemical engineering include:
A __Consequences of safety and quality mistakes
B __Sophistication of process control
C __Environmental control and documentation
D __Dealing with impact of external variables
E X All of the above
Answer: (e) All of these factors are major differences.

3 A practical issue in large-scale chemical operations not normally seen in shorter-term lab operations is:
A __Personnel turnover
B __Personnel protective equipment requirement
C X Corrosion
D __Size of offices for engineers versus chemists
Answer: (c) Corrosion issues are frequently not seen in short term laboratory runs, especially if the lab work is done in glassware. Personnel protective equipment specifications should be the same no matter the scale of the work being done.

4 Issues that complicate large-scale daily chemical plant operations to a much greater degree than laboratory operations include all but which of the following
A __Weather conditions
B __Emergency shutdown and loss of utilities
C __Upstream and/or downstream process interactions
D X Price of company, suppliers, and customer stocks that change minute by minute
Answer: (d) Weather needs to be considered because many large scale chemical process operations are outside without building protection. This subjects process equipment to wide fluctuations in temperature, affecting to some degree any unit operation which is affected by temperature or temperature differential (i.e., reactors, heat exchangers, and distillation columns). Emergency shutdowns and loss of utilities consequences are typically more severe, as well as process changes' impact on directly connected processes. Though prices may be affected by how well we do these things, it is not a direct concern.

5 A chemical engineering unit operation is one *primarily* concerned with
A __A chemical operation using single-unit binary instructions
B X Physical changes within a chemical process system
C __Operations that perform at the same pace
D __An operation that does one thing at a time
Answer: (b) The concept of "unit operations" generally refers to process operations which involve physical changes (separations). However, in such unit operations as distillation, there are multiple unit operations involved.

Chapter 2 Review: Health and Safety

1 Procedures and protective equipment requirements for handling chemicals include all but:
A X Expiration date on the shipping label
B __MSDS sheet information
C __Flammability and explosivity potential
D __Information on chemical interactions
Answer: (a) Though an expiration date is a useful piece of information (especially in food and pharmaceutical packaging), it is not a key requirement in this area. The other are far more important.

2 Start-ups and shutdowns are the source of many safety and loss incidents due to:
A __Time pressures
B __Unanticipated operational and/or maintenance conditions
C __Lack of standard procedures for unusual situations
D X All of the above
Answer: (d) All of these items can and have contributed to significant problems in plant startups.

3 The "fire triangle" describes the necessary elements required to have a fire or explosion. In addition to fuel and oxygen, what is the third item that must be present?

A X Ignition source
B __Lightning
C __Loud noise
D __Shock wave

Answer: (a) An ignition source is required. Shock and lightning may be causes but they are not a general description of what is required. They are sub-sets and examples of ignition sources.

4 The NFPA "diamond," normally attached to shipping containers, indicates all of the following except:

A __Degree of flammability hazard
B __Degree of health hazard
C X Name of chemical in the container
D __Degree of reactivity

Answer: (c) The point of this type of labeling is to give first responders (most of whom will have no knowledge of chemistry) knowledge of the type of material they are dealing with. The name of the chemical is useful, but not important for emergency response with the exception of immediate local responders with whom a local processing facility has excellent close communication.

5 The lower explosive limit (LEL) and upper explosive limit (UEL) tell us:

A X The range of flammability under some conditions
B __The range of flammability under all conditions
C __The upper and lower limits of the company's tolerance for losses
D __The upper and lower limits of the amount of flammable material pumped into a vessel

Answer: (a) UEL and LEL normally refer to limits at atmospheric pressure and the material in pure form. Pressure and the presence of other materials can change the UEL and LEL.

6 Autoignition temperature is the temperature at which:

A __The material loses its temper
B __A material automatically explodes
C X A material, within its explosive range, can ignite without an external ignition source
D __Fire and hazard insurance rates automatically increase

Answer: (c) Autoignition does not mean a material will automatically ignite or explode but it has the potential to do so without deliberate ignition.

7 Toxicology studies tell us all but which of the following:
A __The difference between acute and long-term exposure effects
B __Repeated dose toxicity
C __Areas of most concern for exposure
D X To what degree they are required and how much they cost
Answer: (d) These studies give us only data upon which to make decisions.

8 An MSDS sheet tells us:
A __First aid measures
B __Physical characteristics
C __Chemical name and manufacturer or distributor
D X All of the above
Answer: (d) As required, an MSDS sheet must include all of this information.

9 A HAZOP review asks all of these types of questions except:
A __Consequences of operating outside design conditions
B X What happens to the engineer who makes a bad design assumption
C __Safety impact of operating above design pressure conditions
D __Environmental impact of discharge of material not intended
Answer: (b) Though we might make some assumptions, this is not part of the HAZOP review.

Chapter 3 Review: The Concept of Balances

1 The concept of balances in chemical engineering means that:
A __Mass is conserved
B __Energy is conserved
C __Fluid momentum is conserved
D X All of the above
Answer: (d) All aspects must balance.

2 If a mass balance around a tank or vessel does not "close" and *instrumentation readings are accurate*, then a possible cause is:
A __A reactor or tank is leaking
B __A valve or pump setting for material leaving the tank is incorrect
C __A valve or pump setting for material entering the tank is incorrect
D X Any of the above
Answer: (d) Any of these are possibilities. If a tank is leaking, there should be some type of alarm system to alert that this is happening. The same should be true of the other possible causes.

3 If an energy balance around a reaction vessel shows more energy being formed or released than should be (*and the instrumentation readings are correct*), a possible cause is:

A __Physical properties of the materials have changed

B X A chemical reaction (and its associated heat effects) is occurring that has not been accounted for

C __Insulation has been added on the night shift when no one was looking

D __A buildup of material is occurring

Answer: (b) Need to check to see if all the possible chemistry is understood.

4 If pressure in a pipeline has suddenly dropped, it may be because:

A __A valve has been shut not allowing fluid to leave

B X A valve has been opened, allowing fluid to leave

C __It has calmed down

D __A downstream process has suddenly decided it would like what is in the pipe

Answer: (b) Note that the gauge itself disappearing does not necessarily mean that the pipe has ruptured.

5 Ensuring accurate measurements of pressure, flow, and mass flows is critical to insure:

A __We know what to charge the customer for the product made that day

B __We know when to order replacement parts

C __We know how to check bills from suppliers

D X Knowledge of unexpected changes in process conditions

Answer: (d) Accurate on line measurements of process flows and conditions can alert us, not only to unexpected changes in process conditions, but to confirm that planned changes have produced the desired results.

Chapter 4 Review: Stoichiometry, Thermodynamics, Kinetics, Equilibrium, and Reaction Engineering

1 Stoichiometry determines ratios and kinetics determine:

A __Kinetic energy

B X Rate

C __Energy release

D __Ratio of rate to energy

Answer: (b) Kinetics and kinetic rate constants determine how fast a particular chemical reaction will proceed.

2 Competitive reactions refer to:
A __Reactions that are also practiced by a competitor
B X Multiple reactions that may occur from the same starting raw materials
C __One or more reactions that compete for raw materials based on price
D __One reaction that runs right after another
Answer: (b) A competitive reaction refers to a situation where more than one reaction, producing different products, can occur.

3 The same raw materials, combined in the same ratio, can produce differing products:
A __Yes
B __No
C __Sometimes, depending upon value of the products produced
D X Yes, depending upon reaction conditions
Answer: (d) The same starting materials, when combined and undergoing a chemical reaction, can produce different products depending upon temperature, pressure, and possibly the presence of a catalyst.

4 Thermodynamics of a chemical reaction determine:
A X The amount of energy released or consumed (needed) if the reaction occurs
B __Under what circumstances a reaction will occur
C __Time delay in a reaction starting
D __How dynamic the reaction is
Answer: (a) The overall thermodynamics of a reaction tell us whether a reaction is exothermic (heat releasing) or endothermic (heat consuming).

5 A kinetic rate constant:
A X Is affected by temperature
B __Is not affected by stoichiometry
C __Is not affected by altitude
D __Is affected by size of reaction equipment
Answer: (a) The kinetic rate constant is a function of temperature; the reaction rate may be affected by the other conditions.

6 The rate of a chemical reaction:
A __Can be changed by changing pressure and/or temperature,
B __Will be affected by stoichiometry and ratios of reactants
C __Will be affected by how fast products are removed
D X All of the above
Answer: (d) Any of these variables can affect the actual rate of a reaction (i.e. mole/h. converted or produced). Anything we do to affect actual stoichiometry during a reaction will have an effect.

7 The rate of a chemical reaction is typically______with temperature:

A __Linear

B __Quadratic

C X Logarithmic

D __Semilogarithmic

Answer: (c) Though there can certainly be specific chemical reaction mechanisms that make a generalization a challenge, most chemical reactions respond to a temperature change logarithmically. This means that the rate of reaction responds dramatically to temperature. This is a major concern with exothermic reactions which generate heat. As their rate increases, the rate of heat release increases in the same way, generating possible reactive chemicals concerns.

8 Conversion of a chemical reaction will always be:

A X The same or greater than yield of the same reaction

B __Less than the selectivity to multiple reaction products

C __Unaffected by the kinetic rate constant

D __Different from the selectivity of a reaction

Answer: (a) Conversion refers to the amount of a raw material, entering a chemical reaction, which converts to another product in some percentage. Yield typically refers to conversion to the desired product. Conversion at 100% to desired product would equal 100% yield, but not less.

9 If a calculated heat of a particular reaction is negative (exothermic), it means:

A __We don't want the reaction to occur

B __The heat calculation is incorrect as it should be a positive number

C X Energy is released if the reaction occurs

D __Energy is required to sustain the reaction

Answer: (c) An exothermic reaction is one which has a net release of energy as calculated as the difference between the heats of formation of its products minus its reactants.

10 If a calculated heat of a particular reaction is positive (endothermic), it means:

A __It is good for the reaction to occur

B X Constant energy input is required to sustain the reaction

C __The reaction will never stop once started

D __All of the above

Answer: (b) Endothermic reactions have a positive difference between the heats of formation of products and reactants, thus requiring a constant input of energy to sustain them.

11 Equilibrium in a chemical reaction system can be affected by:
A __Ratio of reactants
B __Temperature
C __Number of possible reactions
D X All of the above
Answer: (d) The equilibrium in a reaction system will be affected by any of these variables, as they all affect the equilibrium constant of a reaction. This situation becomes even more complicated if there is the possibility of more than one chemical reaction occurring.

12 The equilibrium constant K_e refers to:
A __The ratios of reactants to products
B __The ratio of reactants to products under certain conditions
C __The ratio of products to reactants
D X The ratio of products to reactants under specific conditions
Answer: (d) The equilibrium constant for a given reaction is a ratio of products divided by reactants. This constant will change with temperature, and for gases, pressure as well.

13 A change in pressure will most likely affect reaction equilibrium for:
A __Liquid–liquid reactions
B __Liquid–solid reactions
C X Gas–gas, gas–liquid, or gas–solid reactions
D __Reactions using a gas whose price is increasing
Answer: (c) Gases change volume and solubility with pressure, so any system using gases in a reaction, regardless of the type, will be affected by pressure.

14 The total time for a reaction to go to completion is affected by all of these except:
A __Kinetic rate constants
B __Rate of heat removal in an exothermic reaction
C __Stoichiometry of reactants
D X Size of the reactor
Answer: (d) The reaction time is affected by all except the size of the reactor. The reactor size relates to how much of a given reaction conversion or yield we want to accomplish in a given vessel, but it is a consequence of the time calculation, not a cause of it.

15 Catalysts can do these things:
A __Lower the temperature or severity of conditions of a reaction
B __Initiate an exothermic reaction
C __Favor one product over another in a reaction system
D X All of the above
Answer: (d) Catalysts are capable of doing any or all of the above, thus increasing the capability of a reaction system to increase yield or reduce temperature and pressure of reaction systems.

16 The loss of catalyst effectiveness over time is most likely due to:
A __Change in stoichiometry in the feed
B X Poisoning or contamination
C __Change in catalyst vendors
D __The introduction of arsenic into the feed
Answer: (b) Though any of these items listed are possibilities, when a long term steady loss in catalyst efficiency is most likely due to some form of contamination or poisoning that needs to be identified and/or removed.

Chapter 5 Review: Flow Sheets, Diagrams, and Materials of Construction

1 The level of detail contained in a flow sheet, in order of increasing complexity, is:
A __P&ID, mass and energy balance, 3D
B __Mass and energy balance, P&ID, 3D
C X Block flow, mass and energy balance, P&ID, 3D
D __3D, P&ID, mass and energy balance, block flow
Answer: (c) A block flow diagram simply shows connections between process units. Then a mass and energy balance adds numbers to this. A P&ID adds control and instrumentation design, and finally a 3D diagram shows all of this in three dimensions, allowing a much better understanding of the practical aspects of accessing, maintaining, and running the process.

2 Process flow diagrams are important because they:
A __Ensure disk space is used on a process control computer
B X Provide a sense of process stream and equipment interactions
C __Provide a training exercise for new engineers and operators
D __Make effective use of flow sheet software
Answer: (b) Though the other answers are true to some degree, the key value is in showing clearly the interactions between various pieces of equipment, their relationship to each other, as well as a framework to discuss interactions.

3 3D process diagrams are most important because they:
A X Enable personnel to envision the interaction between people and equipment
B __Allow the use of 3D glasses from the movies that otherwise would be thrown away
C __Enable the use of 3D software
D __Show the best location for a security camera
Answer: (a) A three dimension visualization of process equipment can provide valuable information on the practical aspects of how operating personnel can reach valves, escape under emergency conditions, and optimize maintenance.

4 It is important to ensure flow sheets are up to date because:
A __They are used by maintenance personnel to identify connections and equipment
B __They show safety valves and relief systems
C __They are a means of common communication between engineers, operators, and maintenance personnel
D X All of the above
Answer: (d) All of these reasons are important! Frequently changes are made to a process during maintenance or shut downs and the flow sheets are not updated. This is a potential cause of safety and operational hazards.

5 Accurate measurement and knowledge of corrosion rates, as well as what affects them, within process equipment is important because:
A __Pipe vendors need to know when to schedule the next sales call
B __Corrosion meters need to be tested once in a while
C X It is important to understand the estimated life of process equipment and the potential for corrosion products to contaminate process streams
D __We need to keep evacuation plans up to date for equipment failures
Answer: (c) Equipment lifetime and corrosion products entering process streams are both critical concerns.

6 A process fluid with higher water content than one with a lower water content:
A __Will be more corrosive
B __Will be less corrosive
C __Depends on the temperature
D X Can't tell without laboratory data
Answer: (d) Though there are many examples where instincts on corrosion are valid, there are just as many where it is not supported by data. This is what we need and under the conditions the process will run. Example: dry chlorine gas can be handled in steel, but it will "ignite" within a titanium pipe due to a chemical reaction. If the chlorine is wet, steel pipe will rapidly corrode, while titanium has a long life.

Chapter 6 Review: Economics and Chemical Engineering

1 The cost of manufacturing a chemical includes:
A __Capital cost (cost of building the plant)
B __Cost of raw materials
C __Taxes, labor, supplies
D X All of the above
Answer: (d) All of these factors will affect the cost of manufacture.

2 The most important factors in determining the variable cost of manufacture are typically:
A __Shipping costs
B __Labor contract changes
C X Raw material and energy costs
D __Security
Answer: (c) The other factors are usually not as significant as raw materials and energy. There may be very special exceptions when shipping costs and siting of a plant to take advantage of this might be a major factor.

3 If capital costs are 50% of the total cost of manufacture, and the production rate is reduced by 50%, the impact on the product's cost of manufacture will be:
A __10%
B X 25%
C __50%
D __75%
Answer: (b) $0.5 \times 0.5 = 0.25$ or 25%.

4 If the cost of one raw material, representing 20% of a product's total cost, is raised by 25%, the impact on total cost will be:
A X 2.4%
B __4.4%
C __5.4%
D __6.4%
Answer: (a) If this raw material represents 20% of the total cost, then 80% is represented by other factors. If this 20% (0.2) is raised by 25%, we now have 0.2×0.25 or a 5% (0.05). Assuming nothing else changes, the total cost is now 1.05 and this cost impact will be 0.25/1.05 or 2.4%.

Chapter 7 Review: Fluid Flow, Pumps, and Liquid Handling and Gas Handling

1 Total fluid pressure is measured by the sum of:
A X Static pressure and dynamic pressure
B __Dynamic pressure and fluid density
C __Static pressure plus anticipated friction loss
D __All of the above
Answer: (a) Static pressure (height) plus dynamic pressure (due to flow pressure).

2 Laminar flow implies:
A __Pressure drop for the fluid flow is high
B __Fluid is wandering around with no direction
C __Pipes are made from plastic laminates
D X Little or no mixing across the cross-sectional area of a pipe
Answer: (d) The flow rate is low enough so as to prevent any significant mixing across the diameter of the pipe.

3 Turbulent flow implies:
A __Fluid is well mixed across the cross-sectional area of the pipe
B __Pressure drop will be higher than laminar flow
C __There is little or no adhesion between the fluid and the piping wall
D X All of the above
Answer: (d) All of these conclusions are valid in turbulent flow.

4 Turbulent versus laminar flow will affect all but:
A __Pressure drop in the pipeline
B __Mixing in the pipe
C X Cost of the piping materials
D __Pressure drop across valves and instrumentation
Answer: (c) Though turbulent flow could imply higher pressure, this not necessarily the case, so the cost of the piping materials themselves are not necessarily affected.

5 Key fluid properties affecting fluid handling systems include all except:
A __Density
B __Viscosity
C X Residence time in tank prior to pumping
D __Temperature and vapor pressure
Answer: (c) The residence time in the tank will not affect, but the height of the liquid in the tank could.

6 Viscosity characterizes a fluid's resistance to:
A __Being pumped
B __Being held in storage
C __Price change
D X Shear
Answer: (d) The basic definition of viscosity.

7 The viscosity of a fluid is most affected by:
A __Density
B __Pressure
C __Index of refraction
D X Temperature
Answer: (d) Temperature has a logarithmic effect; the other variables have little or no effect.

8 The viscosity of an ideal (Newtonian) fluid reacts to a change in shear at constant temperature by:
A X Remaining the same
B __Increasing
C __Decreasing
D __Need more information to answer
Answer: (a) An ideal fluid does not change viscosity with shear.

9 A dilatant fluid's viscosity _______with shear:
A X Increases
B __Decreases
C __Stays the same
D __Depends on what kind of shear
Answer: (a) Increases (meaning it will thicken).

10 A thixotropic fluid responds to shear by______its viscosity:
A __Increasing
B X Decreasing
C __Not affecting
D __Depending on what kind of shear
Answer: (a) Decreasing.

11 In general, adding solids to a liquid (converting it into a slurry) will ______ its viscosity:
A X Increase
B __Decrease
C __Not affect
D __Can't be known
Answer: (a) Increase (in general). There can be situations, depending upon particle size, concentration, liquid surface tension, and nature of the fluid where this may not be the case, but this would be the starting assumption.

12 The Reynolds number is:
A __Dimensionless
B __A measure of turbulence in flow
C __The ratio of diameter × density × velocity
D X All of the above
Answer: (d) All of the above.

13 A dimensionless number in chemical engineering:
A __Provides a simple way of characterizing an aspect of design
B __Has no units (if calculated correctly)
C __Allows a chemical engineer to estimate relative behavior of an engineering system
D X All of the above
Answer: (d) All of the above.

14 Friction in fluid flow is influenced by all but:
A __Fluid properties
B __Flow rate
C __Piping design characteristics
D X Cost of energy to pump the fluid
Answer: (d) Cost of energy does not affect fluid properties (other than their cost!).

15 Pressure drop in a fluid system can be affected by:
A __Length of piping
B __Number and nature of connections and valves
C __Degree of corrosion on walls
D X All of the above
Answer: (d) The longer the pipe, the greater the pressure drop; each valve or connection adds pressure drop; corrosion can decrease pipe diameter over time, increasing pressure drop.

16 The difference between a centrifugal and positive displacement pumps is:
A __Centrifugal pumps are less expensive
B __Positive displacement pumps have a characteristic curve
C X Centrifugal pumps generate constant pressure; positive displacement pumps put out constant flow
D __It is harder to "dead head" a positive displacement pump versus a centrifugal pump
Answer: (c) Centrifugal pumps balance flow and pressure; positive displacement pumps displace a given amount of volume under constant pressure.

17 Centrifugal pumps require a minimum net positive suction head (NPSH) to operate; otherwise they will cavitate. This can be caused by all but:
A __Improper placement of the pump on an engineering drawing
B X Reducing the level of the liquid feeding the pump
C __Raising the level of a tank into which the pump is discharging
D __Raising the temperature of the feed liquid and raising its vapor pressure
Answer: (b) Reducing the level of the feed will decrease the NPSH available.

18 If the process needs to exceed the minimum NPSH available, what options are available?
A __Raise the height of inlet stream to the pump
B __Lower the temperature of the inlet feed
C __Increase the size of the piping in the system
D X Any of the above
Answer: (d) Any of these suggestions will increase the NPSH available, but more than one may be required.

19 The choice of a flow meter will depend upon:
A __Accuracy required
B __Pressure drop tolerance
C __Cleanliness of fluid
D X All of the above
Answer: (d) All of these factors need to be considered in choosing a flow meter. Dirty fluids will rule out some, high ΔP will rule out others, and accuracy of measurement needed will also be a screening mechanism. Corrosion resistance will also be a factor.

Chapter 8 Review: Heat Transfer and Heat Exchangers

1 An energy balance around a process or piece of equipment requires knowledge of all but:
A __Flow rates and temperatures of flows in and out
B X The speed of the pump feeding the vessel
C __Heat generated by any reaction occurring
D __Heat capacities of streams in and out
Answer: (b) The speed of the pump may contribute to the heat balance, but it will be reflected in the data in (a).

2 The three methods of heat transfer are all but:
A __Conductive
B __Convective
C X Convoluted
D __Radiation
Answer: (c) Maybe in thinking, but not in heat transfer.

3 Conductive heat transfer refers to heat moving:
A __Above
B __Below
C __Around
D X Through
Answer: (d) All the others would be part of convective heat transfer.

4 Convective heat transfer refers to heat moving:
A X In a bulk fashion
B __Only as a function of convective currents
C __On its own
D __None of the above
Answer: (a) Refers to heat transfer occurring through bulk mixing of fluids or gases.

5 Variables that affect the rate of heat transfer are:
A __Flow rates
B __Physical properties of fluids
C __Turbulence within the heat transfer area or volume
D X All of the above
Answer: (d) All of these will affect.

6 If the pipe diameter is increased and all other variables remain the same, the rate of heat transfer:
A __Will increase
B X Will decrease
C __Will stay the same
D __Can't tell without more information
Answer: (b) If everything else stays the same, the Reynolds number and turbulence will decrease, reducing the heat transfer coefficient.

7 If the viscosity of fluids on the shell side is increased, the heat transfer rate:
A __Will increase
B X Will decrease
C __Will stay the same
D __Can't tell without more information
Answer: (b) Any increase in viscosity of fluids or gases anywhere within the heat exchanger will decrease the heat transfer coefficient.

8 The utility fluid is:
A __The fluid that costs less since it is asked to do anything
B __A fluid that can move in either direction
C X The non-process fluid in a heat exchanger
D __A utility that is a fluid
Answer: (c) Refers to the cooling or heating fluid that is not the process fluid.

9 The overall heat transfer coefficient includes the resistance to heat transfer through:
A __The pipe wall
B __The barrier layer on the shell side
C __The barrier layer on the tube side
D X All of the above
Answer: (d) The overall coefficient includes all of these. It is possible to measure the individual components if desired.

10 Design issues with heat exchangers include all but:
A __Area required
B __Corrosion resistance to the fluids
C __Leakage possibilities
D X The dollar to euro conversion at the time of design
Answer: (d) Only ChE's in the financial world impact this; all the other issues are part of design considerations.

11 The primary design limitation of air cooled heat exchangers is:
A __Fan speed
B __Distance from a river or lake
C X Temperature of outside air
D __Contractor's ability to raise or lower the heat exchanger
Answer: (c) Although the other factors can have an impact, the primary limitation is the temperature of the ambient air.

12 Fouling and scaling on a heat exchanger can be caused by:
A X Deposition of hard water salts
B __Softness of the heat exchanger material
C __Use of distilled water as a coolant
D __Poor maintenance
Answer: (a) Inverse solubility of hard water salts are a primary cause.

13 Radiative heat transfer can be an important concern in:
A __Sunburns while working in a chemical plant in Houston
B __Chemicals that are red or yellow
C __Insufficient heat transfer on a cloudy day
D X High temperature processing in the oil and petrochemical industry
Answer: (d) Unless the process temperatures are in the neighborhood of 1000°C, it is unlikely that radiant heat transfer will be a significant issue. Radiation heat transfer is proportional to the fourth power of temperature.

14 High temperature heat transfer fluids are used when:
A __Cold ones are not available
B X It is necessary to transfer heat at high temperature and low pressure
C __Hot water is not available
D __The plant manager owns stock in a company that makes and sells them
Answer: (b) Transferring heat under these conditions would ordinarily require high pressure steam, which is costly.

15 The downside of high temperature heat transfer fluids include all but:
A __Flammability
B __Possible degradation and need to recharge
C __Potential chemical exposure to the process fluid
D X Ability to transfer high temperature heat at low pressure
Answer: (d) This is their primary positive.

Chapter 9 Review: Reactive Chemicals Concepts

1 Reactive chemicals reviews start with an understanding of:
A __How reactive management is to safety incidents
B __A summary of last quarter's reactive chemicals incident reviews
C X The chemical stability of all chemicals being handled
D __The cost of changing storage conditions for gas cylinders
Answer: (c) A basic understanding of the chemical, thermal, and physical stability of all materials being handled is a mandatory first step in this process.

2 Reactive chemicals analysis would include all but the following:
A X Management's reaction to a reactive chemicals incident
B __Shock sensitivity
C __Temperature sensitivity
D __Heat generation during any processing
Answer: (a) Management's reaction may be relevant in terms of what is actually done, but it is not a part of the review process.

3 When considering the reactive chemicals potential of an exothermic chemical reaction, the key consideration is:
A __The cost of cooling vs. heating
B __The cost of relief devices and environmental permits relating to an over-pressured reactor
C X The rate of heat generation vs. the rate of cooling required
D __The possible rise in cost of processing
Answer: (c) A reactive chemical incident is caused by the rate of heat generation being faster than the system's ability to absorb and/or remove the heat, so understanding these relative factors is critical.

4 The reason there is a basic conflict between kinetics and heat transfer is that heat transfer is a linear function and kinetics or reaction rates are typically:
A X Logarithmic with temperature
B __Inversely proportional to pressure
C __Subject to residence times in the reactor
D __Vary with the square root of the feed ratios
Answer: (a) Reaction rates normally increase logarithmically with temperature, meaning that the potential for heat generation is greater than the heat removal rate increase with temperature, which will be linear.

5 A rise in reactor temperature will:

A __Increase the rate of heat removal from the reactor

B __Increase the rate of any chemical reaction occurring

C __Lower the viscosity of any liquids in the reactor, increasing the heat transfer rate

D X All of the above

Answer: (d) A temperature rise will do all of the above. The drop in viscosity (discussed in the chapter on fluid flow) will also potentially increase the heat transfer coefficient, so there may be a slight increase in heat removal rate.

6 An increase in volume used within a chemical reactor will have what effect on the potential for a reactive chemical incident?

A __None

B __Make the system less susceptible

C X Make the system more susceptible

D __Need additional information to answer

Answer: (c) An increase in volume used could increase the heat transfer area available for heat removal (depending on the design of the heat transfer system), but it will also greatly increase the potential energy release from a runaway reaction.

7 A drop in temperature within the reactor will ____the probability of a runaway reaction.

A __Increase

B X Decrease

C __Make no difference

D __Need additional information

Answer: (b) Any drop in temperature will reduce the rate of reaction. It will also reduce the rate of heat transfer removal, but remember the first is logarithmic and the second linear.

8 Improper storage of materials in warehouses can be a source of reactive chemicals incidents if:

A __Moisture-sensitive materials are stored under a leaky roof

B __Oxidizers and reducers are stored next to each other

C __Known compound stability time limits are exceeded

D X Any or all of the above

Answer: (d) Any of these conditions, or their combination, could create a reactive chemicals concern.

Chapter 10 Review: Distillation

1 Distillation is a unit operation based on differences in:
A __Solubility
B __Density
C X Vapor pressure
D __Crystallinity
Answer: (c) Vapor pressure. The difference in volatility is what we use in distillation. The other properties listed can be used in other separation processes, especially liquid–solid systems.

2 A material, solution, or mixture boils when:
A __The solution is rolling around and bubbling violently
B X The sum of all the partial pressures equals the total pressure
C __It's mad
D __The partial pressures exceed the external pressure by 10%
Answer: (b) When the sum of all the partial pressures equals the system pressure, the solution boils. It is important to remember that the system pressure may not be atmospheric pressure.

3 The key determinant in how easy it is to separate a mixture by distillation is the:
A __Volatility of the relatives of the mixture
B __Whether the relatives want to be separated
C __Ability to heat selectively the most volatile component
D X Relative volatility of its various components
Answer: (d) The volatility of one liquid component compared to others in the system is what determines the ease of separation by distillation. The higher the volatility of one component is to another (i.e., higher relative volatility), the easier it is to separate the components by distillation.

4 On a graphical plot of a distillation system, the 45° line represents:
A X The vapor phase and liquid phase having the same composition
B __All phases are created equal
C __One component has 45% more volatility than another
D __One component has 45% less volatility than another
Answer: (a) This is the line at 45° from the horizontal and represents where the liquid and gas have the same composition. In distillation, it is useful in analyzing total reflux situations and minimum number of stages required to perform a particular separation.

5 In a two-component distillation system where the relative volatility is displayed on a y–x graph, a higher relative volatility will be displayed, vs. a 45° line, as:
A __No difference in the lines
B __A small difference in the lines
C X A large difference between the lines
D __Price of company, suppliers, and customer stocks that change minute by minute
Answer: (c) A large difference displays a large relative volatility; a small difference a small one. Smaller relative volatilities indicate more difficult distillation separations.

6 In a batch distillation system, the maximum number of stages of separation possible is:
A X One
B __Depends on relative volatility
C __A function of heating rate
D __A function of the batch size
Answer: (a) Since there is only one stage of vaporization, there is only one state of separation.

7 In a conventional continuous distillation system, the top of the column will always contain:
A __A higher concentration of the less volatile component
B X A higher concentration of the more volatile component
C __A higher concentration of the less dense material
D __A higher concentration of the material desired by the customer
Answer: (b) Since the more volatile component will concentrate in the vapor phase, it will be most concentrated at the top of the column.

8 Returning reflux to a distillation column allows:
A __More energy to be wasted
B __More cooling water to be wasted
C X Multiple vaporizations and condensations, yielding purer top and bottom products
D __More capital expenditures to be wasted on a reboiler and condenser
Answer: (c) Condensing some of the overhead product provides the condensing mechanism for the "boil/condense" aspect of distillation. Without reflux, we have no distillation beyond one stage of separation.

9 Increasing reflux to a distillation column results in:
A __Higher pressure drop
B __Purer overhead product
C __More cooling water to be used
D X All of the above
Answer: (d) Increasing reflux does all of these things. The economics and equipment limitations will determine the degree to which increasing reflux can be increased and is desirable.

10 Decreasing reflux to a distillation column results in all except:
A __Less cooling water and reboiler steam use
B __Lower overhead purity
C X Less intensive process control
D __Pressure drop across the column decreases
Answer: (c) Decreasing reflux results in all of these items except process control. There is no reason to expect that the process control will be any less demanding.

11 The "operating line" of a distillation column represents a graphical display of:
A __The line drawn by the process operators when the process computers are offline
B X The mass balance within the column
C __The line of code that operates the column
D __The line that no one on the operating floor is allowed to cross
Answer: (b) The operating line is a plot of the liquid and vapor composition within the column as opposed to a vapor pressure curve. The distance between it and the vapor–liquid equilibrium line is an indirect indication of the ease of separation by distillation.

12 Varying the reflux ratio in a distillation column allows us to:
A __Adjust the quality of overhead and bottom products
B __React to changes in feed compositions
C __Allow process adjustments to upstream and downstream processes
D X All of the above
Answer: (d) Varying reflux ratio allows all of these.

13 Vacuum distillation can result in all but:
A __Increased energy use
B __Separation of azeotropes
C __Separation of high boiling components
D X Smaller distillation columns
Answer: (d) The use of vacuum can be useful in all of the areas, but the consequence of using vacuum is larger diameter columns, not smaller. The gas law studied earlier predicts that as pressure is reduced, volume is increased.

14 Azeotropes are:
A __Special mixtures of chemicals that come from the tropics
B __Mixtures of chemicals with close boiling points
C X Mixtures of materials whose vapor composition when boiled is the same as the starting liquid
D __Impossible to separate
Answer: (c) When the liquid composition and vapor composition at boiling is the same, we have what is known as an azeotrope. Such a limitation can limit the effectiveness and options in the use of distillation.

15 Ways of separating azeotropes include:
A __Changing pressure
B __Using an alternative separation technique
C __Adding a third component that shifts the vapor–liquid equilibrium
D X All of the above
Answer: (d) Any of these techniques can possibly be used to "break" an azeotrope. Which one is chosen is a function of utility costs, the cost of an alternative separation unit operation, and the limitations of adding additional materials to the system.

16 Bubble cap trays in distillation columns have this key advantage:
A __They trap bubbles
B X Prevent liquid from dropping down on to a lower tray without contacting vapor
C __Relatively expensive
D __High pressure drop
Answer: (b) Because the bubble cap floats up and down against the incoming vapor stream from the tray below, it prevents liquid on the tray from "leaking" down on to the lower tray.

17 Sieve trays have this disadvantage:
A __Low pressure drop
B __Inexpensive and easy to fabricate
C X Can allow weeping and mixing between stages
D __Can allow low molecular weight materials to leak through
Answer: (c) Though the other factors are positives, the fact that there is positive mechanical seal against the down flowing liquid allows some liquid to drop down to the tray below, causing some equilibration and loss of efficiency. Hydraulic design of these type of trays is important.

18 Loose packings used in place of trays:
A __Will usually have lower pressure drop
B __Can be more corrosion resistant
C __Are more likely to breakup due to mechanical shock
D X All of the above
Answer: (d) All of these items are characteristic of packed towers vs. tray towers. Metal packings are less susceptible to breakage during installation and handling than ceramic packings.

Chapter 11 Review: Other Separation Processes

1 Absorption is the process for recovering a gas into a:
A __Solid
B __Another gas
C X Liquid
D __Any of the above
Answer: (c) Liquid. Other unit operations are used in the other choices.

2 Stripping is removal of a gas from:
A X Liquid
B __A reactor
C __A tank truck
D __Any of the above
Answer: (a) This is the opposite of absorption.

3 The key variable that is used in designing an absorber or a stripper is the:
A __Temperature of the liquid
B __Temperature of the gas
C X Henry's law constant
D __External temperature
Answer: (c) Henry's Law Constant. This is the ratio of vapor pressure to mole fraction (in the liquid) at any given temperature.

4 Henry's law constant represents:
A X The ratio of gas partial pressure to gas concentration dissolved in the liquid
B __The inverse of Henry's law variable
C __The approval of Henry to the gas solubility data generated in the lab
D __How much more gas will dissolve in a liquid if the pressure is increased
Answer: (a): This ratio is greatly affected by temperature. The relative Henry's Law Constants tell us to what degree one gas will preferentially be absorbed (or stripped) vs. other gases.

5 In an absorber, the gas enters at the:
A __End
B __Top
C X Bottom
D __Middle
Answer: (c) Gas, with a contaminant or material for recovery, enters at the bottom and is scrubbed by the liquid entering at the top.

6 In a stripper, the liquid enters at the:
A __End
B X Top
C __Bottom
D __Middle
Answer: (b) The liquid, containing a material that cannot be discharged or is recoverable, is fed into the top and gas entering the bottom strips or removes this material.

7 In designing an absorber it is important to take into account:
A __Proper distribution of inlet gas across the bottom of the tower
B __Proper distribution of liquid over the cross sectional area of the tower
C __Potential temperature rise due to heat of gas dissolution
D X All of the above
Answer: (d) All of these variables are important to ensure optimum contact between liquid and gas, as well as to take into account changes in Henry's Law constant due to heat of solution of the gas into the liquid.

8 Demisters may be required at the top of a stripper due to:
A __Fill in void space
B X Control of possible liquid carryover
C __Operators are sad when seeing material being removed from a liquid
D __To supply pressure drop
Answer: (b) Demisters are fine wire devices designed to coalesce fine particle sized mists and collect and send them back to the column.

9 Adsorption is the process for recovering a component from a fluid or gas onto a:
A X Solid
B __Membrane
C __Liquid
D __Any of the above
Answer: (a) Adsorption is the recovery of a component in a gas stream on to a solid adsorbent. Gas recovery into a liquid is absorption.

10 The efficiency of adsorption is governed by:
A __What kind of carbon is used
B __Affinity of the gas for the solid
C __Pore size of the adsorbent
D X All of the above
Answer: (d) All of these variables are important and are most often measure in conjunction with an adsorbent supplier.

11 Variables that can affect the efficiency and selectivity of adsorption include:
A __Temperature
B __Pressure
C __Adsorption isotherms
D X All of the above
Answer: (d) All of these variables are important and can be used individually or collectively to design or improve an adsorption process.

12 Adsorption beds can be regenerated by all of these techniques except:
A __Change in pressure
B __Change in temperature
C X Seriously wishing
D __Purging with a large amount of gas to displace the adsorbed material
Answer: (c) If only it were that easy! Any of these techniques, individually or in combination can be used to design or optimize bed regeneration.

13 Liquid chromatography is a unit operation that utilizes_____to recover and/or separate liquid components:
A __Molecular size
B __Surface charge
C __Liquid–solid surface chemistry
D X Any of the above
Answer: (d) Any of these properties can be used.

14 Ion exchange processes use what functionality bound to a polymer surface to achieve separation:
A X Ionic charge
B __Pore size
C __Differing molecular weight polymer additions
D __Surface roughness
Answer: (a) Ion exchange uses differences in charge and polarity to recover opposite charged materials.

15 Ion exchange beds are regenerated through the use of:
A __Change in pressure
B __Change in temperature
C X Large volumes of the opposite original charge solutions
D __Purging with a large amount of gas to displace the exchanged material
Answer: (c) This operation replaces the original charge on the resin.

16 A serious practical issue when regenerating ion exchange beds is:

A __Using the wrong regenerant solution

B X Hydraulic expansion

C __Noise created

D __Regenerating the wrong bed

Answer: (b) Ion exchange resins are chemically cross linked, not allowing them to dissolve; instead most resins have the capability to absorb liquids and thus can hydraulically expand, especially when regenerated. Extra volume must be allowed to accommodate this physical property.

17 Liquid–liquid extraction is a unit operation involving the use of a material's preference to be dissolved in:

A __One liquid close to its boiling point versus another liquid at room temperature

B __One liquid close to its freezing point versus another liquid at room temperature

C __One liquid close to its critical point versus another liquid near its boiling point

D X One liquid versus another liquid

Answer: (d) While temperature does play a role in design, the primary physical property variable is the relative solubility of one liquid vs. another in a third liquid.

18 To design a liquid–liquid extraction process, the following is needed:

A __A ternary phase diagram

B __Knowledge of densities and density differences

C __Surface tension of process fluids

D X All of the above

Answer: (d) Knowledge of the mutual solubilities, density differences (which liquid is fed at the top for a continuous column) and surface tension (affecting the need for surfactants) and time needed to separate phases after contacting are all important.

19 Operating and design variables for a liquid-liquid extraction operation include:

A __Temperature

B __Contact time

C __Liquid physical properties

D X All of the above

Answer: (d) In addition to the physical property data, the operational variable of temperature (and variation), contact time, and physical properties are all needed to design a practical liquid-liquid extraction unit.

20 Leaching is a unit operation used to:
A __Go back to the days of the gold rush
B __Recover money from a stingy relative
C X Recover a material from a solid via liquid contact
D __Recover a material from a solid via gas contact
Answer: (c) Leaching is used to recover or remove a material from a solid by contacting it with a solution which has a preferential solubility for a component of the solid to be removed or recovered.

21 Membranes separate materials based on the difference in their:
A X Molecular weight and size
B __Desire to go through a very small hole
C __Value and price
D __Cost
Answer: (a) Membranes, having different pore sizes, are used to separate different size gas molecules.

Chapter 12 Review: Evaporation and Crystallization

1 Evaporation involves concentrating:
A __A liquid in a solid
B X A solid in a liquid
C __A gas in a liquid
D __A liquid in a gas
Answer: (b) Evaporation is the removal, either by heat input or vacuum, of a solvent in which a solid is dissolved in. This process increases the concentration of the non-volatile material.

2 The primary design equation for an evaporator considers:
A __Boiling point of the liquid
B __Pressure in the evaporator
C __Temperature difference between the heat source and the boiling point of the solution
D X All of the above
Answer: (d) The design equation is basically Q (energy required) = U (heat transfer coefficient) × A (area available) × ΔT (temperature difference). The boiling point of the solution is part of the ΔT calculation; the pressure affects the boiling point; and the temperature difference is the ΔT.

3 The boiling point of a solution to be evaporated with steam is affected by all but:
A __Pressure
B X Steam price
C __Concentration of dissolved salts
D __Temperature differential between heat source and boiling point of the solution
Answer: (b) The steam price may affect the cost of the evaporation step, but not technical aspects as mentioned in the other three choices.

4 The boiling point of a salt solution will ____ with increased concentration of the dissolved salt:
A __Decrease
B __Need more information to answer
C X Increase
D __Rise by the square root of concentration change
Answer: (c) Any increase in salt concentration will increase the boiling point. (d) is not correct as the relationship is not the same for all salts.

5 If the steam pressure feeding an evaporator slowly decreases with time, the salt concentration leaving the evaporator will _____over the same time period:
A __Increase
B X Decrease
C __Stay the same
D __Depends (on what?) _____
Answer: (b) If the steam pressure drops, its temperature will also drop, lowering the ΔT driving force.

6 Salt solution carry over into the vapor phase of an evaporator can be minimized through the use of:
A __Prayer
B __Filters
C __Cyclones
D X Demisters
Answer: (d) Demisters are usually used to accomplish this. A cyclone is the type of equipment more often used to remove dry particles from gas streams.

7 Multi-effect evaporators function by:
A X Using the vapor from one stage to vaporize another stage
B __Using the "super-effect" of steam
C __Condensing the first stage vapor and then boiling it a second time
D __Taking advantage of off-peak power prices
Answer: (a) Vapor driven off one stage of evaporation is used as the energy source to boil the solution in a second stage. This requires either pressure or vacuum as a driving force.

8 Film evaporators are used primarily for:
A X Temperature-sensitive and high viscosity materials
B __Emotionally sensitive materials
C __Hold your temper materials
D __All of the above
Answer: (a) Film evaporators (typically wiped continuously in some fashion) are used in these cases to minimize residence time in the evaporator.

9 The basic difference between evaporation and crystallization is that the solution is concentrated by:
A __Use of diamonds
B X Cooling
C __Any type of heat sources that is available except steam
D __Suction
Answer: (b) Though cooling can be used to evaporate under vacuum, crystallization most often involves cooling of a solution to precipitate out solids in solution to recover them for further treatment.

10 The types of crystals produced in a crystallizer are affected by:
A __Phase diagram
B __Rate of cooling
C __Amount of agitation
D X All of the above
Answer: (d) Any of these parameters will affect the types of crystals produced. The phase diagram (if it exists) will define and put limits on the operating parameters that can be used.

11 A phase diagram for a salt and solvent will determine all but:
A __The types of crystals that will be formed
B __Where various hydrates will form as a function of temperature and concentration
C X Cost incurred to operate at a particular point within the phase diagram
D __How to produce certain types of salt hydrates
Answer: (c) The phase diagram, if it exists, will define where it is possible to operate, but says nothing directly about the cost of operating within it at any point.

Chapter 13 Review: Liquid–Solids Separation

1 The driving force for filtration is:
A X Pressure differential
B __Concentration differential
C __Temperature differential
D __Temperament differential
Answer: (a) Pressure differential is what forces the liquid through a medium, leaving solids behind.

2 A pre-coat on a filter medium may be required if:
A __It is cold in the filter operations room
B __The operating instructions say so
C __The particle size of the solids is greater than the hole size in the filter medium
D X The particle size of the solids is smaller than the hole size in the filter medium
Answer: (d) A particle size smaller than the pore size of filter medium can quickly plug the filter. A pre-coat of a large particle, inert material is typically used to provide a physical barrier to this happening.

3 If the filtration is run under constant pressure, the flow rate will ____ with time:
A X Drop
B __Stay the same
C __Increase
D __Need more information to know
Answer: (a) At constant pressure, the bed of filtered solids will increase, providing additional pressure drop. If the feed pressure is not increased, the flow of liquid exiting the filter will decrease.

4 If the filtration is run to produce constant volume output, the pressure will ____with time:
A __Drop
B __Stay the same
C X Increase
D __Rise by the cube of the change in flow
Answer: (c) This is the opposite situation compared to question 3. In order to maintain a constant flow of filtrate, the pressure (or differential pressure) will need to be increased.

5 Raising the solids concentration in a filter feed, with other variables unchanged, will _____the filtration rate:
A __Increase
B X Decrease
C __Not affect
D __Drop by the square root of the solids concentration change
Answer: (b) Increased solids will increase filter cake volume, thus increasing pressure drop and decreasing filtrate rate.

6 Increased compressibility of a filtration cake will _____the filtration rate over time:
A __Increase
B X Decrease
C __Stay the same
D __Increase by the square of the compressibility
Answer: (b) A higher compressibility will decrease the void volume between solids, reducing the filtrate rate over time.

7 A centrifuge adds what force to enhance filtration rate:
A __Gravity
B __Pressure
C X Centrifugal/centripetal
D __Desire for a faster rate
Answer: (c) Rotational force is added to the existing pressure differential.

8 The rate of filtration in a centrifuge is proportional to the ____of the rotational speed:
A __Linearity
B __Square root
C __Cube
D X Square
Answer: (d) This is similar to any other rotational device's response to rotational speed.

Chapter 14 Review: Drying

1 Drying is defined as the removal of ___from a solid material:
A X Solvent
B __Coolant
C __Water
D __Spirits
Answer: (a) The solvent might be water, but not always!

2 Drying rate is affected by all but:
A __Solvent concentration at any point in time
B X Cost of vacuum or steam
C __Agitation within the dryer
D __Temperature difference between solid and heating medium
Answer: (b) The other three variables can all affect the rate of drying, but the cost of the drying energy source only affects the cost, not the rate.

3 Key variables in the design and operation of a spray dryer include:
A __Liquid or slurry to gas ratio
B __Viscosity of fluid and pressure drop across the spray nozzle
C __Temperature difference between hot drying gas and liquid
D X All of the above
Answer: (d) All of these process and physical property values affect the design and operation of a spray dryer.

4 Design issues with rotary dryers include:
A __Possible need for dust recovery
B __Particle size degradation
C __Dust fires and explosions
D X All of the above
Answer: (d) All of these are important, especially concerns about dust fires and explosions. Since this type of dryer can reduce particle size through attrition, it can enhance the probability of dust explosions.

5 Freeze drying is a potential practical drying process if:
A __A freezer is available
B X The S–L–V phase diagram allows direct sublimation at a reasonable vacuum
C __It is desired to have a cold product
D __The plant manager owns stock in a freeze dryer manufacturing company
Answer: (b) We must know the basic solid–liquid–vapor phase diagram to be able to judge the feasibility and cost of a freeze drying process.

6 A drying rate curve tells us:
A __How fast a solid will dry
B __How much it will cost to dry a solid to a particular residual water or solvent level
C X The drying rate curve as a function of residual water or solvent
D __How the cost of drying is affected by the rate of inflation
Answer: (c) A drying rate curve shows the residual moisture or solvent level as a function of time under any given process condition. This information, along with the cost of any drying process or equipment, is used to determine options on a drying process.

7 Auxiliary equipment frequently needed for a drying process include:
A X Cyclones and scrubbers
B __Backup feed supply
C __Customer to purchase product
D __Method of measuring the supply chain
Answer: (a) Dryers frequently generate dust as particle size is reduced through attrition. This often requires the use of cyclones and/or scrubbers to minimize the loss and discharge of solid particles into the atmosphere. There may also be environmental regulations requiring such dust control measures.

Chapter 15 Review: Solids Handling

1 The energy used in particle size reduction is primarily a function of:
A __Price of energy
B X Ratio of incoming particle size to exiting particle size
C __Size of the hammers or pulverizers
D __Strength of the operator running the equipment
Answer: (b) The ratio of size reduction is the key variable. The greater this ratio is, the more energy is required.

2 Cyclones have primarily one very positive design feature and one very negative design feature:
A X No moving parts and sharp cutoff in particle separation
B __No motor and low particle collection
C __Can be made in the farm belt but cannot collect large size corn cobs
D __Are small and can make a lot of noise
Answer: (a): They have no moving parts (they use impact and geometry), but their capabilities are limited in terms of sharpness of separation. It is critical to match performance with expectations through testing.

3 A key solids characteristic in assessing solids cohesion is:
A __Particle size
B __Height of solids pile
C __Slope of laziness
D X Angle of repose
Answer: (d) The angle of repose is an indirect measurement of particle cohesive strength. The greater is it, the more difficult it is for particles to flow in a storage situation.

4 A poorly designed hopper can cause:
A __No flow when the bottom valve is opened
B __Segregated particle size flow
C __Surges in flow behavior
D X All of the above
Answer: (d) All of these things are possible results from a poorly designed hopper.

Chapter 16 Review: Tanks, Vessels, and Special Reaction Systems

1 Simple storage tanks can be hazardous due to:
A __Leakage
B __Overfilling and under filling
C __Contamination
D X All of the above
Answer: (d) Any of these conditions are cause for concern. Leakage and contamination may be longer term or quality issues, but under filling and over filling can be catastrophic in terms of consequences.

2 A key design feature in an agitated vessel (its Z/T ratio) is:
A X Its height-to-diameter ratio
B __Which company manufactured it
C __The engineer who designed it
D __When it was placed into service
Answer: (a) The height to diameter ratio is critical in terms of how effective the mixing and agitation is both top to bottom and side to side. The physical properties of the material are also critical in terms of the difficulty in achieving uniformity.

3 Choosing an agitator for a tank will be affected by:
A __Densities of liquids and solids
B __Viscosity of liquids
C __Ratios of gases/liquids/solids
D X All of the above
Answer: (d) Every one of these variables will have a significant effect on agitation efficiency and energy use. It is important to measure these variables at the temperature and pressure conditions that will actually exist.

4 The significance of top-to-bottom agitation will be affected by:
A __Gas and liquid densities and their changes over time
B __Formation of solids as a reaction proceeds
C __Necessity for liquid/solid/gas mixing
D X Any of the above
Answer: (d) All of these are important variables and the relative importance of each will determine optimum tank geometry. It is useful to envision extremes such as a gas with a slow reaction in a viscous solvent reacting with a solid slurry.

5 Shaft horsepower requirements for an agitated vessel will be MOST affected by:
A __Air flow available and ability to clean an exiting air stream
B __Physical properties of materials being mixed and agitated
C __Particle size degradation
D X All of the above
Answer: (d): As with question #5, all of these can be important and the degree to which each is important will be a function of the vessel's function and the physical property differences.

Chapter 17 Review: Chemical Engineering in Polymer Manufacture and Processing

1 Polymers are long chains of:
A __Polys
B __Mers
C __Various mixtures of polys and mers
D X Monomers
Answer: (d) Polymers are long chains of monomers (ethylene, styrene, etc.) whose double bonds have been activated is such a manner that they can react with each other to produce long chains.

2 Latex polymers are unique in that they:
A __Are used in tennis shoes
B __Are stretchable
C X Are suspensions of polymers in solution
D __Are combinations of thermoplastic and thermoset polymers
Answer: (c) Latexes are not actually polymers themselves, but suspensions of polymers (via the use of surface chemistry on the polymer particles). When applied, for example as paints, the water/solvent evaporates, leaving a polymer film behind.

3 The uniqueness of elastomers is that they_____
A X Have a T_g below room temperature
B __Have a T_g at room temperature
C __Have a T_g above room temperature
D __Have a T_g that is controllable
Answer: (a) Elastomers have a glass transition temperature (where the polymer is not rigid) below room temperature. A conventional rubber band is an example of such a polymer.

4 *cis-* and *trans*-isomers differ in:
A X Where functional groups are positioned on the monomer backbone
B __Their preference for being *cis* or *trans*
C __Their ability to change positions
D __Cost
Answer: (a) *Cis* and *trans* refer to whether a functional group is positioned on only one side or alternative sides of a polymeric double bond. This positioning can greatly affect physical properties.

5 "Condensation" polymerizations are unique in that they:
A __Produce polymers that condense when it is cold
B X Split out a molecule during the polymerization process
C __Prevent another monomer from entering the process
D __Provide a barrier to another polymerization process occurring
Answer: (b) This type of polymerization involves chemical reactions as well as the joining of monomers. Typically a molecule such as water or hydrochloric acid (HCl) is produced when two different monomers are polymerized. This allows new composition polymers to be produced, but it also adds the complication of removing the "split out" molecule from the desired product and the process.

6 Polymer additives can be used to affect or change:
A __Color
B __Flowability
C __Ability to foam
D X All of the above
Answer: (d) Polymer capability and appearance can be enhanced or modified in any of these areas through the addition of additives or latent properties (i.e., foaming) later activated by the user.

7 A differential scanning calorimetry (DSC) tells us:
A __Softening temperature range of a polymer
B __Softening temperature ranges within a polymer
C __Degree of crystallinity within a polymer
D X All of the above
Answer: (d) A well run DSC will tell us all of the above properties, most of which are related to the temperature of use of the polymer.

8 Chemical engineering challenges presented in processing polymers include all but:
A __High viscosity
B __Slow heat transfer rates
C X Knowledge of the polymers being processed
D __Difficulty in mixing
Answer: (c) Knowledge of the polymer name or type is not a chemical engineering challenge; it is a basic piece of knowledge. The chemical engineering challenges are the other three process and product variables.

9 The technical challenges in recycling of plastics and polymers can be affected by all but:
A __Purity of plastics and ability to separate into various types
B __Energy value of plastics
C X Legislation
D __Landfill availability
Answer: (a) Unfortunately, legislation (especially that based on politics and not technical information) does not change the nature of the technical challenges represented in the other three answers.

Chapter 18 Review: Process Control

1 Proper process control is necessary because:
A __Specifications must be met on products produced
B __Environmental emissions must be within permitted limits
C __Safety and reactive chemicals issues must be controlled
D X All of the above
Answer: (d) All of these aspects are important. The ranking of them may vary from process to process.

2 The elements of a process control loop include all but:
A __Method to measure
B X Manager's approval
C __Way to evaluate the measurement versus what is desired
D __Corrective action
Answer: (b) The manager's approval has nothing to do with what is required! Hopefully the manager understands the decisions on control loop architecture and why they are the way they are.

3 Characteristics of a process which affect how it should be controlled include all but:
A __Customer quality requirements
B __Response time of measurements
C __Degree of deviation permitted around the set point
D X The mood of the process operator that day
Answer: (d) The process must be controlled according to these specifications no matter the mood of anyone in the control room!

4 The least sophisticated process control strategy is:
A X On–off
B __Off–on
C __Off sometimes, on other times
D __On–on, off–off
Answer: (a) The control system turns on the "final control element" when the measurement deviates, then turns off when it again reaches the set point desired.

5 Integral control has a key advantage in that it:
A __Has the capability to integrate
B X Will eventually result in the process reaching its desired set point
C __Oscillates around the desired set point
D __Oscillates in a controlled manner around the desired set point
Answer: (b) The controlled value may oscillate in a slowly degrading manner for a while, but the integrating action will eventually bring the controlled variable to its desired set point. Settings on the integral loop can be used to control the degree of oscillation and the time to reach the desired value.

6 Derivative control allows a control system to:
A X Anticipate a change in process based on input changes
B __Preplan batch operations
C __Provide a more uniform break structure for process operators
D __React sooner to post process changes
Answer: (a) If it is known how a process will respond to an input change, then derivative control can be used to anticipate the change by making control element settings prior to the downstream change being measured.

7 If a process has a slow reaction rate process feeding into a very fast final reaction process, the type of process control likely to be used is:
A __Proportional
B __Follow the leader
C __Wait 'til it tells me
D X Cascade
Answer: (d) One control loop design will be incorporated within another to be appropriate to the particular process.

8 Control valves can be characterized, in terms of their process response, by all but:
A __Capacity
B __Speed of response
C __Type of response
D X Materials of construction
Answer: (d) Materials of construction will have little or no effect on how the valve responds. They will certainly affect costs, weight, etc.

9 A control valve curve plots:
A __% Open versus % closed
B __% Closed versus flow rate
C X % Flow versus % open
D __Flow rate versus air pressure supplied
Answer: (c) The other plots may be useful to know, but they are not the standard method of plotting control valve response.

10 A water cooling control valve, with loss of utilities, should fail to open if:
A __An endothermic reaction is being run
B X An exothermic reaction is being run
C __The utility water rates are temporarily dropping
D __There is no mechanic available to close
Answer: (b) Since an exothermic reaction is releasing heat, it is critical that any cooling system fail in a way to maximize cooling rate.

11 A control valve, with loss of utilities, should fail to close if:
A __An endothermic reaction is being run
B X It controls feed to an exothermic reaction
C __There is one person strong enough to close it
D __There is no other option
Answer: (b) A feed to an exothermic (heat producing) reaction must be closed with loss of utilities to prevent further heat generation.

12 A control room variable may not indicate the actual process conditions if:
A __The sensor has failed or been disconnected
B __A physical property effect has not been taken into account
C __The operator is not looking at the correct screen
D X Any of the above
Answer: (d) Any of these can cause a control room screen or data display to be incorrect. It is imperative that a combination of operating discipline, layers of protection, and HAZOP reviews ensure that this possibility is minimized.

Index

Chemical Engineering for Non-Chemical Engineers, First Edition. Jack Hipple.